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Synthesis guide for cross-country movement

Alexander R. Pearson

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ORIGINAL CONTAINS COLOR PLATES: ALL DDC REPRODUCTIONS WILL BE IN BLACK AND WHITE

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This report provides step-by-step instructions for compiling a cross-country movement map from previously prepared factor overlays. The information on the factor overlays is combined, or synthesized, manually with or without the aid of a simple mathematical model. Three synthesis methods are given: (1) using a mathematical model; (2) using a mathematical model with a programable calculator (HP-97), and (3) using a qualitative, non-mathematical procedure.

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Preface

This guide for cross-country movement (CCM), is one in a series of Analysis and Synthesis Guides to be produced. It is anticipated that after some modification to format and content these guides will be published as Department of Defense Technical Manuals. In this regard, critical comments and suggestions are requested by the authors.

The authors gratefully acknowledge the technical assistance of Messrs. A.D. Hastings, A.H. Reimer, and H.F. Barnett, Terrain Analysis Center U.S. Army Engineer Topographic Laboratories (ETL) in the development of the CCM synthesis procedures, and of Messrs. R.J. Orsinger and K.O. Kurtz Geographic Sciences Laboratory, ETL, in the design of the calculator program.

This study was conducted under DA Project 4A762707A855, Task C, Work Unit 11, 'Military Geographic Analysis Technology.'

This study was done under the supervision of A.C. Elser, Chief, MGI Data Processing and Products Division and K.T. Yoritomo, Director, Geographic Sciences Laboratory.

COL Daniel L. Lycan, CE was the Commander and Director and Mr. Robert P. Macchia was Technical Director of the Engineer Topographic Laboratories during the report preparation.

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I. INTRODUCTION

Cross-country movement maps enable commanders to judge the relative ease of off-road movement for foot troops and vehicles. Off-road movement can be easy or difficult, depending on several terrain factors and on the ability of troops or vehicles to cope with certain terrain factors. The terrain factors include vegetation, slope, drainage, surface roughness, built-up areas, and soil. These factors are mapped on terrain factor overlays. The cross-country movement (CCM) map shows the combination of these factors and prediction of their combined effects on the movement of men * and machines. This combining of factors and their effects is called synthesizing. The CCM map is, then, a synthesis of terrain factor overlays.

This synthesis guide shows three methods of combining specific terrain factor overlays and using their legends and tables to determine speed categories for specific vehicles. Two methods use a simple mathematical model to determine speed categories. The third method uses a qualitative approach to determine movement categories. These methods enable the production of one CCM map for each type of vehicle concerned; i.e. one CCM map will not provide movement data for more than one type of vehicle. ** If movement data for more than one vehicle is required, more than one CCM map will be required.

The synthesis process means taking specific factor overlays out of the data base, placing a sheet of frosted mylar on the overlays one at a time, and tracing all the map unit boundaries on the different overlays onto the single sheet of mylar. This sheet of mylar, called the Complex Overlay, will become the base from which the CCM map will be made. With the math model, speed values for the combined factors on the Complex Overlay can be found. With the qualitative method, general speed categories for the combined factors on the Complex Overlay can be created without using a mathematical model.

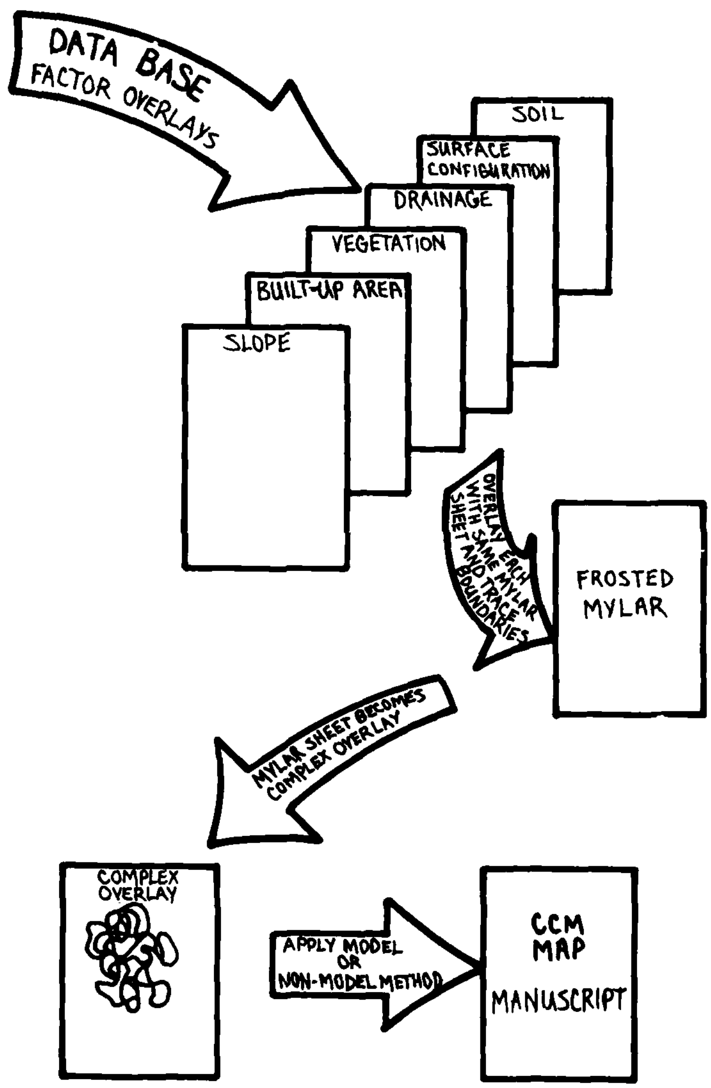
The following diagram shows the basic steps in the general synthesis process for CCM:

---

* Cross-country movement for foot troops is not treated in this guide.

** In some instances, the map can present data for more than one vehicle, but the computations must be done separately for each vehicle and also for each season.

Synthesis Process



II. MATHEMATICAL MODEL AND SYNTHESIS PROCEDURES - COMPUTED WITHOUT A PROGRAMABLE CALCULATOR

A. Introduction.

The mathematical model used in this guide * enables the analyst to assign an expected maximum vehicle speed to specific terrain. The model is a sequence of simple equations that take the maximum vehicle speed for an unobstructed flat surface and reduce that speed by calculated factors representing terrain elements that would prevent a vehicle from achieving its maximum speed (figure 1). These calculated factors reflect the slowing effect of certain slopes, vegetation, soil, surface roughness, and watercourses.

$$S_1 = M - \frac{(S)(M)}{G}$$

S_1 = speed after slope effect (kph)
M = vehicle maximum speed (kph)
S = slope (%)
G = vehicle gradability (%)

$$S_2 = S_1 \times F_1 \text{ or } S_1 \times F_2$$

S_2 = speed after vegetation and slope effect (kph)

$$F_1 = \frac{\text{stem spacing - mean stem diameter - vehicle width}}{2 \times \text{vehicle width}}$$

$$F_2 = 1 - \frac{(\text{stem diameter})^2 \times \text{vehicle width}}{(\text{vehicle override diameter})^2 \times (\text{stem spacing})}$$

$$S_3 = S_2 \times F_3$$

S_3 = final speed after surface roughness, vegetation, and slope effect (kph)

F_3 = a factor ≤ 1 by which surface roughness reduces vehicle speed

$$S_4 = S_3 \times F_4$$

S_4 = speed after soil, surface roughness, vegetation, and slope considered (kph)

$$F_4 = \frac{\text{Rated Cone Index - Vehicle Cone Index, 1 pass}}{\text{Vehicle Cone Index, 50 passes - Vehicle Cone Index, 1 pass}}$$

Drainage hindrance is evaluated only as GO or NO GO.

Figure 1. The Cross-Country Movement Mathematical Model

The equations in the model are solved at different stages in the synthesis process. In section B, S_1 (speed after the effect of slope is considered) and F_1 through F_4 (inhibiting factors for vegetation, surface

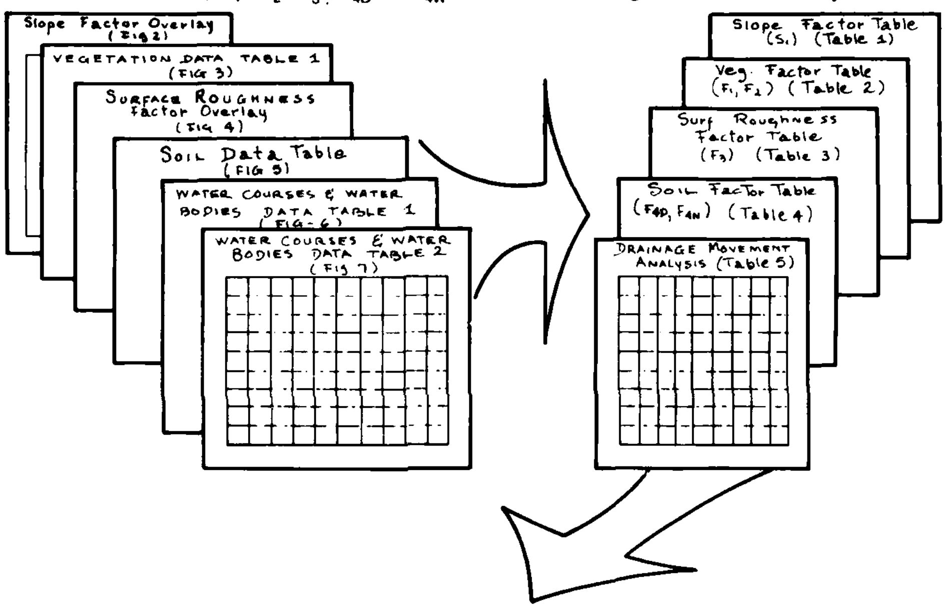
* An experimental model developed in the Geographic Sciences Lab., ETL.

roughness and soil) are calculated, and water obstacles are analyzed. In section C, factor overlays for slope, vegetation, watercourses, surface roughness, and soil are combined (synthesized) to create the factor complex overlay. In section D, vehicle speeds are computed for each area on the Complex Overlay.

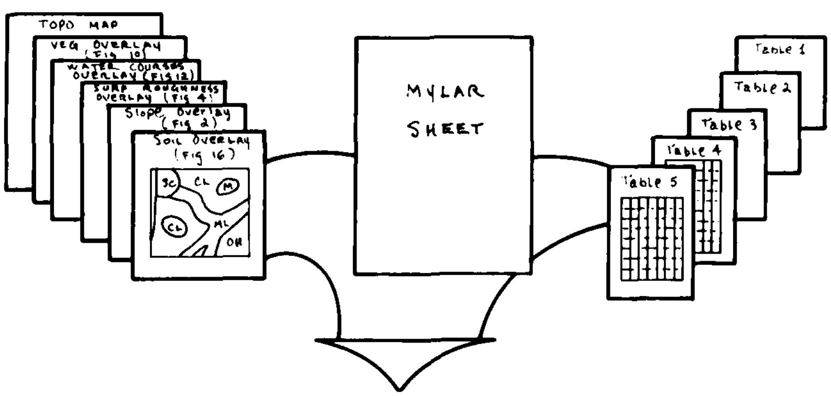
The following summaries and illustrations show the sequence of analysis steps found in these sections:

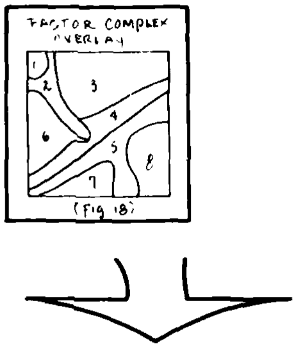
Flow Diagram

Compute S_1, F_1, F_2, F_3, F_{4D} & F_{4W} and Do Drainage Obstacle Analysis.

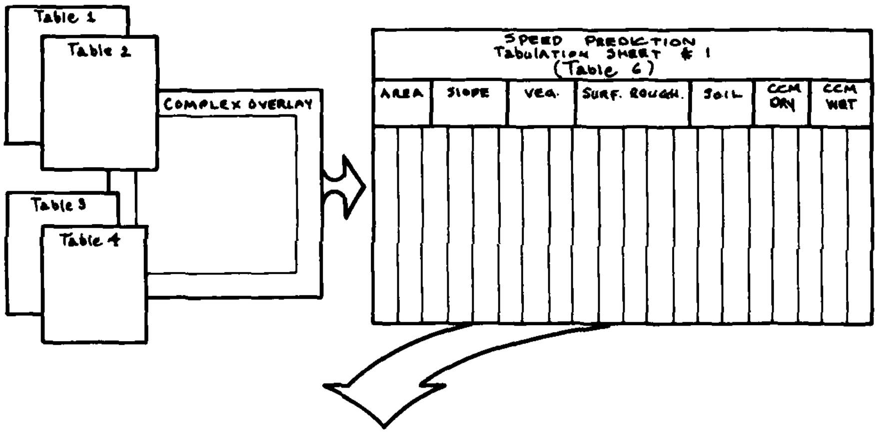


Prepare Factor Complex Overlay.

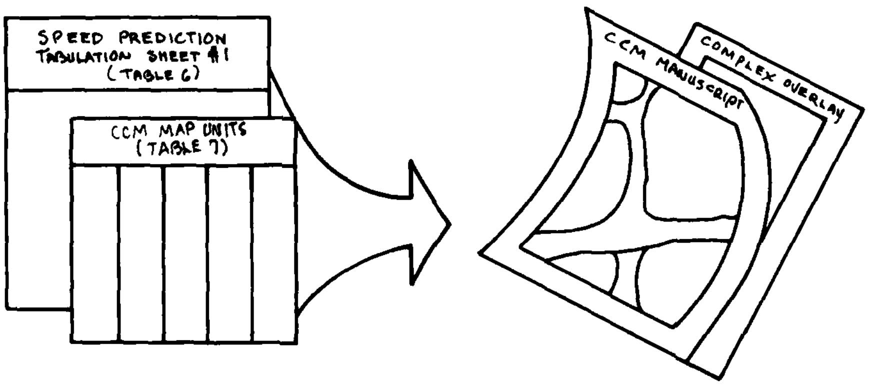




Prepare Speed Prediction Tabulation Sheet & Compute Speed for each Map Unit on Complex Overlay.



Assign Speed Classes to each Map Unit, Trace Complex Overlay, and Complete CCM Manuscript.



B. Procedures for Factor Calculation

Step 1. Determine vehicle(s) for which the CCM map(s) is (are) being prepared, and whether the CCM map will be for the wet or dry season or both.

Step 2. Refer to the vehicle performance characteristics in table 9.

Step 3.

a. If the vehicle under consideration is listed below, S_1 has already been calculated and listed in table 10, therefore, proceed to Step 5. If the vehicle under consideration is NOT listed below, proceed to Step 3b to calculate S_1.

Vehicle
X-M1
M-60
T-62
T-72

b. Pull the Slope Factor Overlay out of the data base (figure 2). Using the legend for this overlay, make a Slope Factor Table like that in table 1.

Step 4.

a. Calculate S_1 for each map unit in the legend of the Slope Factor Overlay by substituting vehicle values and slope values into the following equation and solving the equation:

$$S_1 = M - \frac{(S)(M)}{G}$$

where: S_1 = vehicle speed adjusted for slope effects.

G = vehicle gradability in percent (%), found in table 9.

S = highest slope in map unit category in percent (%), found in table 1.

M = vehicle maximum speed in kilometers per hour (kph), found in table 9.

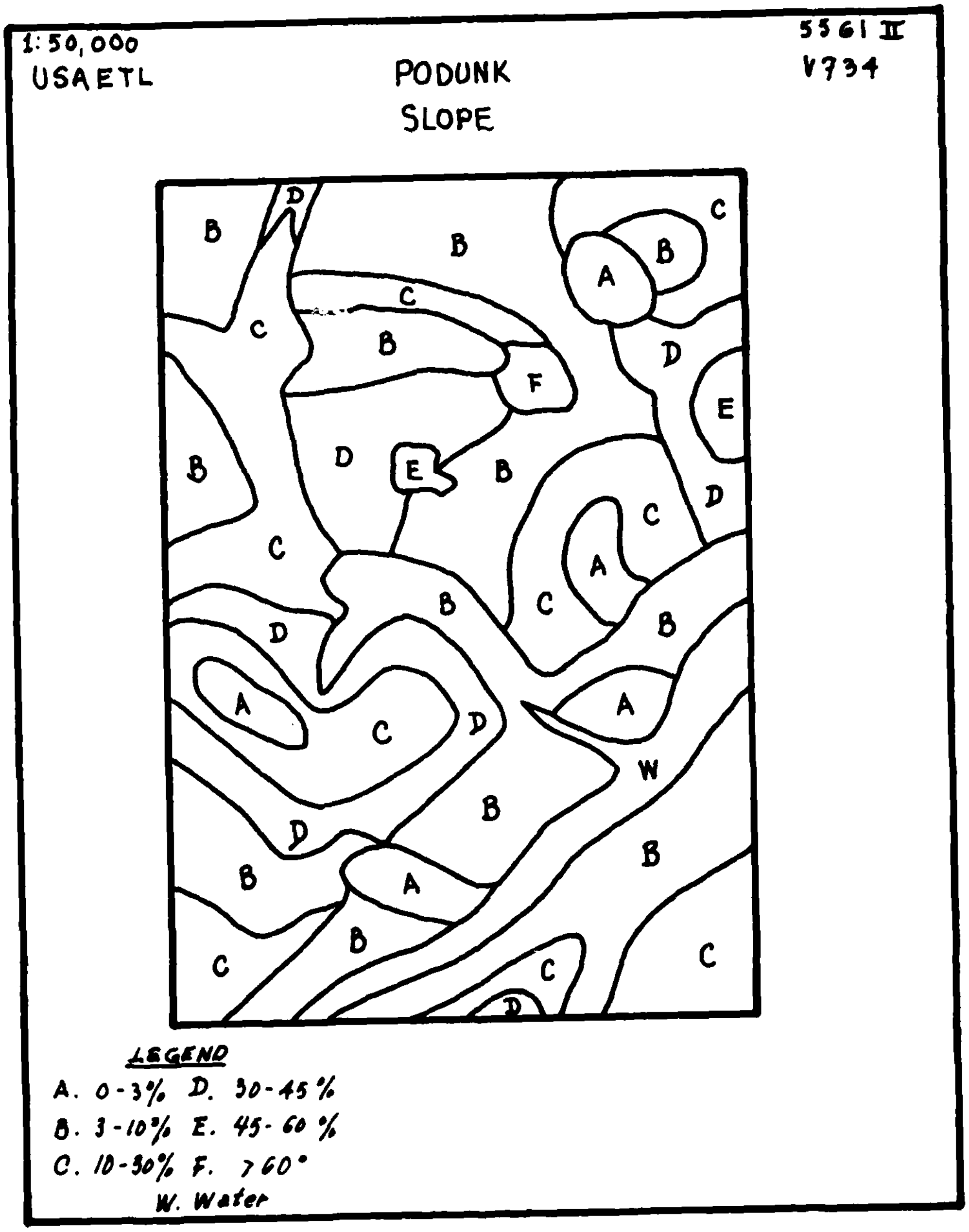


Figure 2. Sample Slope Factor Overlay

Table 1

MAP UNIT	SLOPE (%)	S_1 (kph)	NO GO
A	3	45.6	
B	10	40	
C	30	24	
D	45	12	
E	60	0	X
F	>60	0	X

$$S_1 = M - \frac{(S)(M)}{G}$$

M = Max. Vehicle Speed = 48 kph
S = Ground Slope, %
G = Max. Slope Vehicle Can Negotiate = 60%

Table 1. Sample Slope Factor Table (S_1) for M-60 Tank

Sample Calculation:

Given: $G = 60\%$

$S = 10\%$

$M = 50$ kph

Then: $$S_1 = 50 - \frac{(10)(50)}{60}$$

$$= 50 - \frac{500}{60}$$

$$= 50 - 8.33$$

$$= 41.67 \text{ kph}$$

b. If $S_1 < .5$, the speed situation is NO GO. Mark an "X" under the NO GO column in the Slope Factor Table (table 1) for map units where $S_1 < .5$.

c. Record in the Slope Factor Table (table 1) the value of S_1 for each map unit.

Step 5. Pull Vegetation Data Table 1 (figure 3) out of the data base. (Retain the Slope Factor Overlay for later use.) Make a Vegetation Factor Table like that in table 2. Fill in the Map Unit and Stem Spacing columns using the information listed in Vegetation Data Table 1. Fill in the Mean Stem Diameter column with the numbers in that column on Vegetation Data Table 1 divided by 100. For example, if a mean stem diameter listed on Vegetation Data Table 1 is 18, then .18 must be listed on the Vegetation Factor Table (table 2).

Step 6.

a. *Find the override diameter in meters for the vehicle concerned* (table 9).

b. Compare the mean stem diameter in meters to the override diameter value for each map unit recorded in table 2. If the mean stem diameter (SD) is greater than the override diameter (OD), i.e. SD > OD, calculate F_1 as shown in "c" below. If the mean stem diameter (SD) is less than or equal to the override diameter (OD), i.e. SD $\leq$ OD, calculate F_1 as shown in "c" below and, also, F_2 as shown in "g" below.

c. Calculate F_1 for each map unit in table 2 by substituting *vehicle values and vegetation values into the following equation and* solving:

VEGETATION DATA TABLE 1
STEM DIAMETERS, CANOPY HEIGHT AND CANOPY CLOSURE

[illegible]	NUMBER STEMS PER HECTARE	MEAN STEM DIAM.	STEM SPACING	NUMBER [illegible] PER HECTARE																								MEAN HEIGHT		CANOPY CLOSURE			
				< [illegible] (cm)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30-35 (cm)	[illegible]	[illegible]	45-50 (cm)	[illegible]	[illegible]	60-65 (cm)	[illegible]	70-75 (cm)	75-80 (cm)	80-85 (cm)	90-100 (cm)	100-110 (cm)	110-120 (cm)	120-130 (cm)	130-140 (cm)	140-150 (cm)	150+ (cm)	[illegible]	[illegible]	DEC FEB	MAR MAY	[illegible]	OCT [illegible]
1	-	-																										-	-	-	-	-	-
2	100	21	11.1		5	15	60	5	10		5																	6	2	40	40	40	40
3	210	25	7.6		3	7	8	175	7	8	2																	8	3	50	50	50	50
4	1200	33	3.2			50	100	25	75	600	150	200																16	5	50	80	100	30
5	-	-	-																									-	-	-	-	-	-
6	300	26	6.4			20	30	125	100	25																		8	2	80	80	80	50
7	-	-	-																									-	-	-	-	-	-
8	250	40	7.0				25	50	175	25	25	25																8	3	15	40	50	40
9	-	-	-																									-	-	-	-	-	-
10	50	60	15.7											8	35	5	2											20	4	40	50	60	50
11	250	83	7.0				10		30				10							125	25	50						22	3	100	100	100	100
12	1000	32	3.5				100	100	50	500	100	50	100															14	2	80	80	80	80
13	-	-	-																									-	-	-	-	-	-
14	100	15	11.1		13	75	12																					4	1	15	20	30	20
15	75	15	12.8		13	50	7	5																				4	2	20	30	40	30
16	-	-	-																									-	-	-	-	-	-
17	-	-	-																									-	-	-	-	-	-
18	50	60	15.7											8	35	4	3											20	4	30	50	70	50
19	115	15	10.3		13	75	12																					4	1	60	60	60	60
20	900	42	3.7			25	50	25	50		525		75	10	90		50											14	2	25	60	100	60
21	1262	30	3.1		56	110	100	115	56	112	90	74	19	26														18	3	30	50	100	50
22	500	93	4.9											25		50		50		250		50		50		25		30	5	100	100	100	100

Figure 3. Sample Vegetation Data Table 1

MAP UNIT	STEM SPACING (m)	MEAN STEM DIA. (m)	F_1	F_2	NO GO
1	–	–	–	–	
2	11.1	.21	1.0		
3	7.6	.25	.51		
4	3.2	.33	-.10		X
5	–	–	–	–	
6	6.4	.26	.35		
7	–	–	–	–	
8	7.0	.40	.41		
9	–	–	–	–	
10	15.7	.60	1.0 ~~1.6~~		
11	7.0	.83	.35		
12	3.5	.32	-.06		X
13	–	–	–	–	
14	11.1	.15	1.0	.67	
15	12.8	.15	1.0 ~~1.2~~	~~.72~~	
16	–	–	–	–	
17	–	–	–	–	
18	15.7	.60	1.0 ~~1.6~~		
19	10.3	.15	0.90	~~.65~~	
20	3.7	.42	-.05		X
21	3.1	.30	-.11		X
22	4.9	.93	.05		

$$F_1 = \frac{SS - SD - W}{2W}$$

$$F_2 = 1 - \frac{(SD)^2 \times W}{(OD)^2 \times (SS)}$$

- If SD > OD find F_1 only.
- If SD ≤ OD find F_1 & F_2 and use largest positive value.
- Neither F_1 nor F_2 can exceed 1. If F value exceeds 1, reduce to 1. ($F_1 \not> 1$, $F_2 \not> 1$)
- Neither F_1 nor F_2 can be less than 0. If F value is 0 or minus, passage is blocked, use 0. ($F_1 \not< 0$, $F_2 \not< 0$)

SS = Stem Spacing
SD = Stem Diameter
W = Vehicle Width (3.63m)
OD = Vehicle Override Diameter (.15m)

Table 2. Sample Vegetation Factor Table (F_1/F_2) for M-60 Tank

$$F_1 = \frac{SS - SD - W}{2W}$$

SS = stem spacing in meters, listed in table 2.

SD = mean stem diameter at breast height in meters, listed in table 2.

W = vehicle width in meters, found in table 9.

Sample calculation:

Given: SS = 7.6 meters

SD = .25 meters

W = 3.63 meters

Then: $F_1 = \frac{7.6 - .25 - 3.63}{7.26}$

$= \frac{3.72}{7.26}$

$= .51$

d. If F_1 is greater than 1, ($F_1 > 1$), let F_1 equal 1, ($F_1 = 1$). Record the value 1 in table 2.

e. If F_1 is less than or equal to 0, ($F_1 \leq 0$), let F_1 equal 0, ($F_1 = 0$). Record 0 in table 2, and mark an "X" in the NO GO column of table 2.

f. If F_1 is between 0 and 1, ($0 < F_1 < 1$), record the calculated value in table 2.

g. Calculate F_2 for each map unit where the mean stem diameter (SD) is less than or equal to the override diameter (OD), i.e. ($SD \leq OD$), by substituting values into the following equation and solving:

$$F_2 = 1 - \frac{W\ (SD)^2}{SS\ (OD)^2}$$

SD = mean stem diameter at breast height in meters, listed in table 2.

W = vehicle width in meters, found in table 9.

OD = vehicle override diameter in meters, found in table 9.

SS = stem spacing in meters, listed in table 2.

Sample calculation:

Given: W = 3.63 meters

SD= .15 meters

SS= 11.1 meters

OD= .15 meters

Then: $F_2 = 1 - \frac{(3.63)\ (.15)^2}{(11.1)(.15)^2}$

$= 1 - \frac{(3.63)\ (.0225)}{(11.1)\ (.0225)}$

$= 1 - \frac{.082}{.250}$

$= 1 - .328$

$= .672$

$= .67$

h. If F_2 is less than or equal to 0, ($F_2 \leq 0$), let F_2 equal 0, ($F_2 = 0$). Record 0 in table 2.

i. If F_2 is greater than or equal to 1, ($F_2 \geq 1$), let F_2 equal 1, ($F_2 = 1$). Record 1 in table 2.

j. If F_2 is between 0 and 1, ($0 < F_2 < 1$), as in the sample calculation above, record the value of F_2 in table 2. For the sample calculation, the value .67 would be recorded in table 2.

Step 7.

a. In table 2 there may now be some map units which have values for both F_1 and F_2. Compare these values to see which is larger.

b. If the F_1 value is larger than the F_2 value, ($F_1 > F_2$), cross out the F_2 value on table 2.

c. If F_1 equals 0, ($F_1 = 0$), and there is no F_2 value, place an "X" in the NO GO column.

d. If F_1 and F_2 are both 0, ($F_1 = 0$ and $F_2 = 0$), place an "X" in the NO GO column.

e. If F_2 is larger than F_1, ($F_2 > F_1$), cross out the F_1 value on table 2.

f. If F_1 and F_2 have the same value, ($F_1 = F_2$), cross out the F_1 value on table 2.

Step 8. Pull the Surface Roughness Factor Overlay (figure 4) out of the data base. Using the legend on the overlay, make a table like that in table 3.

Step 9.

a. Pull the Soil Data Table (figure 5) out of the data base. Make a Soil Factor Table like that in table 4.

b. Use the information in the Soil Data Table to fill in the map unit column of table 4 with each map unit's number and Unified Soil Classification System (USCS) symbol for the top 15 to 30 cm (centimenters) of the soil, if available. Record the associated RCI_{dry} and RCI_{wet} for this soil layer as found in the Soil Data Table. (If this specific layer of soil is not given on the Soil Data Table, simply use what is given.)

c. For map units with the following Unified Soil Classification System (USCS) symbols shown on the Soil Data Table, fill in the F_4 DRY and F_4 WET columns on table 4 with the number 1:

<u>USCS SYMBOLS</u>

GW
GP
SW
SP

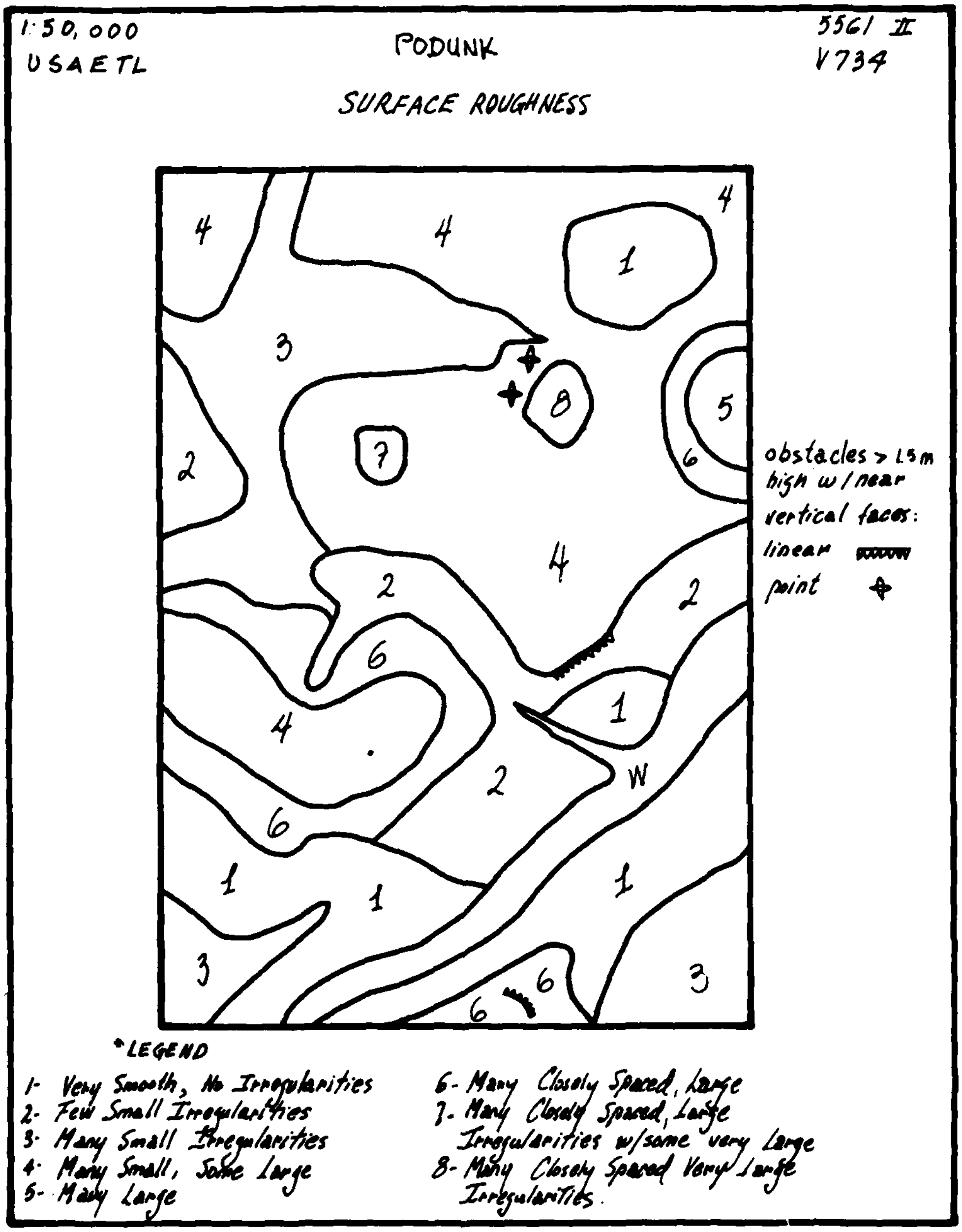
d. For the remaining map units on table 4, calculate F_4 DRY and F_4 WET using the following equations:

$$F_{4D} = \frac{RCI_D - VCI_1}{VCI_{50} - VCI_1} \qquad F_{4W} = \frac{RCI_W - VCI_1}{VCI_{50} - VCI_1}$$

where F_{4D} = speed reduction factor owing to soil in dry state.

F_{4W} = speed reduction factor owing to soil in wet state.

RCI_D = rating cone index for the soil type under dry conditions, found in the Soil Data Table (figure 5) or table 11.



*The legend for surface roughness given here is for illustration purposes only. At the time of printing, surface roughness categories were still under development as part of the forthcoming Terrain Analyst Guide for surface configuration. It is anticipated that the final surface roughness categories will be as few as four: smooth, irregular, broken, rugged.

Figure 4. Sample Surface Roughness Factor Overlay

MAP UNIT	TRACKED VEHICLE (F_{3T})	WHEELED VEHICLE (F_{3W})
1	1	1
2	1	.9
3	.9	.5
4	.5	.3
5	.3	.1
6	.2	NO-GO
7	.1	NO-GO
8	NO-GO	NO-GO

Note: F_3 Values are the same for all Tracked Vehicles and for all Wheeled Vehicles

Table 3. Sample Surface Roughness Factor Table (F_{4T}/F_{4W}) for Tracked & Wheeled Vehicles

SOIL DATA TABLE

MAP UNIT NUMBER	SOIL PROFILE			DEPTH TO BEDROCK (m)	STATE OF GROUND												STONINESS	RCI		REMARKS
	HORIZON	DEPTH (cm)	USCS SYMBOL		J	F	M	A	M	J	J	A	S	O	N	D		WET	DRY	
1	A	0-10	SC	25	S	F	W	W	W	W	M	M	W	M	W	W		50	130	
	B	10-25	CL																	
	C	25-30	S																	
2	A	0-20	MH	40	S	F	W	W	W	W	W	M	W	M	W	W		15	115	
	B	20-40	ML																	
	C	40-60	CH																	
3	A	0-20	GW	50	S	F	W	W	W	W	M	M	W	M	W	W		100	165	
	B	20-40	GD																	
	C	40-50	SP																	
4	A	0-30	CL	60	S	F	W	W	W	W	M	M	M	W	W	W		40	125	
	B	30-40	CH																	
	C	40-50	ML																	
5	A	0-10	GP	100	S	F	W	W	W	W	M	M	M	W	W	W		80	160	
	B	10-40	ML																	
	C	40-50	CH																	
6	A	0-20	SP	60	S	F	W	W	W	W	M	M	M	W	W	W		80	150	
	B	20-30	SW																	
	C	30-35	SC																	

Figure 5. Sample Soil Data Table

MAP UNIT NUMBER	SOIL PROFILE			DEPTH TO (m) BEDROCK	STATE OF GROUND												STONINESS	RCI		REMARKS
	HORIZON	DEPTH (cm)	USCS SYMBOL		J	F	M	A	M	J	J	A	S	O	N	D		WET	DRY	
7	A	0 - 28	CL	?	S	F	W	W	W	W	M	M	M	W	W	W		40	125	
	B	28 - 30	SC																	
	C	30 - ?	ML																	
8	A	0 - 15	CH	60	S	F	W	W	W	M	M	M	D	W	W	W		65	140	
	B	15 - 25	GC																	
	C	25 - 39	GW																	
9	A	0 - 70	GP	50	S	F	W	W	W	M	M	M	D	M	M	M		80	165	
	B	70 - 100	GW																	
	C	100 - 120	GC																	
10	A	0 - 20	OH	?	S	F	W	W	W	W	W	W	W	W	W	W		5	110	
	B	20 - 40	CH																	
	C	40 - ?	SM																	
11	A	0 - 20	ML	?	S	F	W	W	W	M	M	M	D	M	W	W		25	120	
	B	20 - 30	CL																	
	C	30 - ?	SC																	
12	A	0 - 40	ML	30	S	F	W	W	W	W	M	M	M	W	W	W		25	120	
	B	40 - 50	SM																	
	C	50 - 60	MH																	

Figure 5 (Continued).

SOIL FACTOR TABLE FOR M-60 TANK

MAP UNIT	DRY			WET		
	RCI	F_{4D}	No-Go	RCI	F_{4W}	No-Go
1 (SC)	130	~~2.9~~ 1		50	.55	
2 (MH)	115	~~2.0~~ 1		15	-.2	X
3 (GW)		1			1	
4 (CL)	125	~~2.2~~ 1		40	.33	
5 (GP)		1			1	
6 (SP)		1			1	
7 (CL)	125	~~2.2~~ 1		40	.33	
8 (CH)	140	~~2.5~~ 1		65	.88	
9 (GP)		1			1	
10 (OH)	110	~~1.8~~ 1		5	-.44	X
11 (ML)	120	~~2.1~~ 1		25	0	X
12 (ML)	120	~~2.1~~ 1		25	0	X

$$F_{3D} = \frac{RCI_D - VCI_1}{VCI_{50} - VCI_1}$$

$$F_{3D} = \frac{RCI_W - VCI_1}{VCI_{50} - VCI_1}$$

RCI_D = Rating Cone Index, Dry State

RCI_W = Rating Cone Index, Wet State

VCI_1 = Vehicle Cone Index, one pass

VCI_{50} = Vehicle Cone Index, fifty passes

Table 4. Sample Soil Factor Table (F_{4D} & F_{4W}) for M-60 Tank (F_4 cannot exceed 1.0)

RCI_W = rating cone index for soil type under wet conditions, found in the Soil Data Table (figure 5) or table 11.

VCI_1 = vehicle cone index for one pass, found in table 9.

VCI_{50} = vehicle cone index for 50 passes, found in table 9.

Sample Calculation:

Given: $RCI_D = 46$

$VCI_1 = 45$

$VCI_{50} = 60$

Then: $F_{4D} = \dfrac{46 - 45}{60 - 45}$

$= \dfrac{1}{15}$

$= .07$

Record the F_4 values for these map units in table 4. If any F_4 value is greater than 1, ($F_{4D} > 1$ or $F_{4W} > 1$), change it to 1, ($F_{4D} = 1$ or $F_{4W} = 1$).

Step 10. Pull the Watercourses and Water Bodies Data Tables (figures 6 and 7) out of the data base. (Put the soil overlay aside for later use.) Using the Watercourses and Water Bodies Data Tables, make a Movement Analysis of Drainage Features table like table 5.

a. List the feature (watercourse or water body) ID number in the first column of table 5, and the segment letters in the second column.

b. Refer to the vehicle performance characteristics table in table 9 and extract the following performance characteristics; record in table 5.

PERFORMANCE CHARACTERISTIC	COLUMN OF TABLE 5
Max. fording depth w/o snorkel	4a
Max. vertical obstacle height	5a
Vehicle approach angle	6a
Max. stream velocity vehicle can cross (m/s)	7a
Vehicle Cone Index, 1 pass (VCI_1)	8a

c. Use Watercourses and Water Bodies Data Tables 1 and 2 (figures 6 and 7), and enter the data for each segment of each feature in table 5. If only a dry season CCM map is to be prepared, enter data for dry season only. If only a wet season CCM map is to be prepared, enter data for wet season only. If CCM maps are to be prepared for both wet and dry seasons, enter data for both wet and dry seasons. As each entry is made, compare it with the preceding entry in the row for the vehicle performance. If the watercourse value exceeds that of the vehicle performance, record NO GO in the following space and stop the analysis for that segment.

Bank height and bank slope conditions are considered together as shown in figure 8.

BANK HEIGHT	BANK SLOPE	MOVEMENT CONDITION
>Vehicle Vertical Obstacle Capability	>Vehicle Approach Angle	No Go
>Vehicle Vertical Obstacle Capability	<Vehicle Approach Angle	Go
<Vehicle Vertical Obstacle Capability	Any	Go

Figure 8. Bank Condition Analysis

5561 III	5561 I	5561 IV	5561 II
5561 III		5561 III	V733
5560 IV	5560 I	5560 IV	July 2001

SCALE OF BASE MAP 1 50 000
USAETL

Watercourses and Water Bodies Data Table 1

HYDROGRAPHIC FEATURE				DRY GAP WIDTH IN METERS	SEASONAL DEPTH, WIDTH AND VELOCITY INFORMATION: HIGH WATER CONDITIONS					LOW WATER CONDITIONS					BANK INFORMATION: RIGHT BANK				LEFT BANK				MAX DISCHARGE CU M/S	CROSS SECTION SKETCH
ID NO	LOCAL NAME	CLASS	SEG LETTER		MONTH(S)	DEPTH (M) MIN	DEPTH (M) MAX	WATER WIDTH IN METERS	VEL MPS	MONTH(S)	DEPTH (M) MIN	DEPTH (M) MAX	WATER WIDTH IN METERS	VEL MPS	HEIGHT IN METERS	SLOPE IN DEGREES MIN	SLOPE IN DEGREES MAX	MATERIAL	HEIGHT IN METERS	SLOPE IN DEGREES MIN	SLOPE IN DEGREES MAX	MATERIAL		
1	Short Branch	Stream	a	20	Mar	0.5	1.0	10	3.1	Sept	0.3	0.5	9	1.8	1.5	10	12	GP	1.0	9	12	GP	740	
2	Long Branch	Stream	a	15	Mar	0.2	0.5	8	3.0	Sept	0.1	0.3	5	2.0	0.5	10	12	SG	0.5	10	—	GP	250	
			b	24	Mar	1.0	1.1	16	2.5	Sept	0.5	0.7	12	1.5	2.0	15	—	CL	1.5	12	15	CL	300	
3	Woods Creek	Stream	a	14	Mar	0.3	0.6	10	2.1	Sept	0.0	0.2	3	0.5	0.6	—	6	MH	1.2	7	10	MH	150	
			b	22	Mar	0.5	1.0	15	2.0	Sept	0.2	0.5	10	0.7	2.2	8	10	CH	2.0	10	12	CH	200	
4	Nabeco Creek	Stream	a	12	Mar	0.1	0.4	12	2.6	Sept	0.0	0.2	5	0.3	1.2	10	—	SC	2.0	15	20	SC	150	
			b	20	Mar	0.1	0.6	18	2.5	Sept	0.1	0.4	12	1.0	2.0	6	—	GP	3.0	10	—	GP	200	
			c	36	Mar	0.5	1.0	25	2.0	Sept	0.2	0.6	20	0.8	1.5	8	15	GP	2.0	6	—	GP	300	
			d	40	Mar	1.6	2.5	35	1.5	Sept	1.0	1.5	30	0.5	1.6	7	—	SM	1.0	4	—	OH	350	
			e	50/150	Mar	2.0	3.5	40/135	1.0	Sept	1.5	2.0	35/100	0.3	4.0	10	12	SM	0.2	9	—	OH	400	
5	Powell Creek	Stream	a	14	Mar	0.2	0.4	10	2.0	Sept	0.0	0.2	8	1.0	2.0	6	10	CH	1.0	2	5	CH	100	
			b	20	Mar	0.3	0.5	18	2.0	Sept	0.1	0.4	15	1.0	3.0	—	5	CH	2.0	—	4	CH	150	
			c	31	Mar	0.5	1.2	25	1.5	Sept	0.3	0.9	22	0.5	3.0	5	10	CS	4.5	6	10	CS	200	
			d	38	Mar	1.5	2.5	35	1.0	Sept	1.0	2.0	30	0.5	2.4	20	—	CL	4	—	5	CG	250	
6	Tom Cat Run	Stream	a	21	Mar	0.3	0.5	19	0.8	Sept	0.0	0.3	15	0.2	1.0	3	10	CL	0.6	5	15	CL	?	

Figure 6. Sample Watercourses and Water Bodies Data Table 1

5561 III	5561 I	5561 IV	5561 II
5561 III		5561 III	V733
5560 IV	5560 I	5560 IV	July 2001

SCALE OF BASE MAP 1 50 000
USAETL

Watercourses and Water Bodies Data Table 1

HYDROGRAPHIC FEATURE				DRY GAP WIDTH IN METERS	SEASONAL DEPTH, WIDTH AND VELOCITY INFORMATION										BANK INFORMATION								MAX DISCHARGE CU M/S	CROSS SECTION SKETCH
					HIGH WATER CONDITIONS					LOW WATER CONDITIONS					RIGHT BANK				LEFT BANK					
ID NO	LOCAL NAME	CLASS	SEG LETTER		MONTH(S)	DEPTH (M) MIN	DEPTH (M) MAX	WATER WIDTH IN METERS	VEL MPS	MONTH(S)	DEPTH (M) MIN	DEPTH (M) MAX	WATER WIDTH IN METERS	VEL MPS	HEIGHT IN METERS	SLOPE IN DEGREES MIN	SLOPE IN DEGREES MAX	MATERIAL	HEIGHT IN METERS	SLOPE IN DEGREES MIN	SLOPE IN DEGREES MAX	MATERIAL		
7	Pine Run	Stream	a	11	Mar	0.2	0.5	8	1.9	Sept	0.0	0.3	5	0.2	2	6	10	CM	5	10	16	CM	100	
			b	20	Mar	0.3	1.0	15	1.5	Sept	0.2	0.6	10	0.1	4	10	8	ML	2	5	—	ML	200	
8	Pato-moke River	Stream	a	150/200	Mar	3.0	5.0	100/175	2.0	Sept	2.0	3.0	75/150	1.0	—	—	—	—	5	30	34	CG	—	
			b	200/300	Mar	3.0	5.0	150/200	2.0	Sept	2.0	3.0	100/175	1.0	—	—	—	—	6	30	35	CG	—	
			c	300/400	Mar	3.5	5.5	260/350	2.0	Sept	2.5	3.5	200/300	1.0	--	-	-	—	0.5	—	16	ML	—	
			d	150/225	Mar	3.0	5.0	100/200	2.0	Sept	2.0	3.0	75/150	1.0	5		30	CG					—	
			e	225/400	Mar	3.0	5.5	200/350	2.0	Sept	2.5	3.5	200/300	1.0	10	25	40	CG					—	
9	Choptank Creek	Stream	a	20	Mar	0.6	1.0	12	2.5	Sept	0.4	0.6	10	0.6	4	10	14	SM	2	—	15	SM	—	
			b	30	Mar	1.5	2.0	25	2.5	Sept	1.0	1.5	20	0.5	5	15	20	SM	4	—	30	SM	—	
			c	40	Mar	2.0	7.0	36	2.0	Sept	1.5	3	32	0.8	5	—	10	SM	6	20	—	SM	—	

Figure 6 (Continued).

Watercourses and Water Bodies Data Table 2

HYDROGRAPHIC FEATURES				BOTTOM CONDITIONS		TIDAL INFLUENCE			WATER QUALITY					ICE CONDITIONS													OBSTACLES	
											ANALYSIS			NO. OF ICE DAYS PER MONTH														
ID NO	LOCAL NAME	CLASS	SEG NO	MATERIAL	SLOPE IN DEGREES	MAX MOS	MIN MOS	DAILY RANGE IN METERS	ID NO	SAMPLE DATE	CHEM	PPM mg/L	GEN CLASS	1	2	3	4	5	6	7	8	9	10	11	12	MAX ICE THICKNESS CM	ID NO	DESCRIPTION SKETCH
1	Short Branch	Stream	a	GP	2	—	—	—	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	10	—	—
2	Long Branch	Stream	a	GS	3	—	—	—	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	10	—	—
			b	GS	2	—	—	—	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	10	—	—
3	Woods Creek	Stream	a	GP	3	—	—	—	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	10	—	—
			b	GP	2	—	—	—	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	10	—	—
4	Neabsco Creek	Stream	a	Rock	4	—	—	—	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	10	—	—
			b	GW	3	—	—	—	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	10	—	—
			c	GP	2	—	—	—	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	10	—	—
			d	GS	2	—	—	—	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	10	—	—
			e	MH	1	—	—	—	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	10	—	—
5	Powell Creek	Stream	a	Rock	4	—	—	—	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	10	—	—
			b	GP	3	—	—	—	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	10	—	—
			c	GW	2	—	—	—	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	10	—	—
			d	SC	2	—	—	—	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	10	—	—
6	Tom Cat Run	Stream	a	SP	2	—	—	—	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	10	—	—
7	Pine Run	Stream	a	CH	2	—	—	—	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	10	—	—
			b	CH	2	—	—	—	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	10	—	—

Figure 7. Sample Watercourses and Water Bodies Data Table 2

Watercourses and Water Bodies Data Table 2

HYDROGRAPHIC FEATURES				BOTTOM CONDITIONS		TIDAL INFLUENCE			WATER QUALITY					ICE CONDITIONS													OBSTACLES	
											ANALYSIS			NO OF ICE DAYS PER MONTH														
ID NO	LOCAL NAME	CLASS	SEG NO	MATERIAL	SLOPE IN DEGREES	MAX MOS	MIN MOS	DAILY RANGE IN METERS	ID NO	SAMPLE DATE	CHEM	PPM (mg L)	GEN CLASS	1	2	3	4	5	6	7	8	9	10	11	12	MAX ICE THICKNESS (CM)	ID NO	DESCRIPTION/SKETCH
8	Patamoke River	Stream	a	ML	1	Apr	July	1.0	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	15	—	———
			b	ML	1	Apr	July	1.0	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	15	—	———
			c	ML	1	Apr	July	1.0	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	15	—	———
			d	ML	1	Apr	July	1.0	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	15	—	———
			e	ML	1	Apr	July	1.0	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	15	—	———
9	Chop Tank Creek	Stream	a	SC	—	—	—	—	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	10	—	———
			b	CH	—	—	—	—	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	10	—	———
			c	CL	—	—	—	—	—	—	—	—	—	5	15	1	0	0	0	0	0	0	0	0	2	10	—	———

Figure 7 (Continued).

MOVEMENT ANALYSIS OF DRAINAGE FEATURES FOR M-60 TANK

1	2	3	4a	4b	4c	5a	5b	6a	6b	6c	7a	7b	7c	8a	8b	8c
			WATER DEPTH			BANK HEIGHT AND BANK SLOPE					WATER VELOCITY			BOTTOM CONDITIONS		
ID NO	SEG	SEASON	VEH FORD DEPTH (m)	WATER DEPTH (m)	GO NO GO	VEH (m)	BANK HEIGHT (m)	VEH A A ( )	BANK SLOPE ( )	GO NO GO	VEH (mps)	WATER VEL (mps)	GO NO GO	VCI	BOTT RCI WET	GO NO GO
1	a	Wet	1.22	1.0	Go	.91	1.5	43	10	Go	3.4	3.1	Go	25	80	Go
		Dry		0.5	Go							1.8	Go			Go
2	a	Wet	1.22	0.5	Go	.91	0.5	43	10	Go	3.4	3.0	Go	25	90	Go
		Dry		0.3	Go							2.0	Go			Go
	b	Wet	1.22	1.1	Go	.91	2.0	43	15	Go	3.4	2.5	Go	25	90	Go
		Dry		0.7	Go							1.5	Go			Go
3	a	Wet	1.22	0.6	Go	.91	1.2	43	7	Go	3.4	2.1	Go	25	80	Go
		Dry		0.2	Go							0.5	Go			Go
	b	Wet	1.22	1.0	Go	.91	2.2	43	10	Go	3.4	2.0	Go	25	80	Go
		Dry		0.5	Go							0.7	Go			Go
4	a	Wet	1.22	0.4	Go	.91	2.0	43	15	Go	3.4	2.6	Go	25	Rock	Go
		Dry		0.2	Go							0.3	Go			Go
	b	Wet	1.22	0.6	Go	.91	3.0	43	10	Go	3.4	2.5	Go	25	90	Go
		Dry		0.4	Go							1.0	Go			Go
	c	Wet	1.22	1.0	Go	.91	2.0	43	8	Go	3.4	2.0	Go	25	80	Go
		Dry		0.6	Go							0.8	Go			Go
	d	Wet	1.22	2.5	No-Go	.91		43			3.4					
		Dry		1.5	No-Go											
	e	Wet	1.22	3.5	No-Go											
		Dry		2.0	No-Go											
5	a	Wet	1.22	0.4	Go	.91	2.0	43	6	Go	3.4	2.0	Go	25	Rock	Go
		Dry		0.2	Go							1.0	Go			Go
	b	Wet	1.22	0.5	Go	.91	3.0	43	5	Go	3.4	2.0	Go	25	80	Go
		Dry		0.4	Go							1.0	Go			Go
	c	Wet	1.22	1.2	Go	.91	3.0	43	6	Go	3.4	1.5	Go	25	90	Go
		Dry		0.9	Go							0.5	Go			Go
	d	Wet	1.22	2.5	No-Go											
		Dry		2.0	No-Go											

Table 5. Sample Movement Analysis of Drainage for M-60 Tank

MOVEMENT ANALYSIS OF DRAINAGE FEATURES FOR M-60 TANK

ID NO	SEG	SEASON	WATER DEPTH: VEH FORD DEPTH	WATER DEPTH: WATER DEPTH (m)	WATER DEPTH: GO NO-GO	BANK HEIGHT AND BANK SLOPE: VEH (m)	BANK HEIGHT AND BANK SLOPE: BANK HEIGHT (m)	BANK HEIGHT AND BANK SLOPE: VEH AA ( )	BANK HEIGHT AND BANK SLOPE: BANK SLOPE ( )	BANK HEIGHT AND BANK SLOPE: GO NO-GO	WATER VELOCITY: VEH (mps)	WATER VELOCITY: WATER VEL (mps)	WATER VELOCITY: GO NO-GO	BOTTOM CONDITIONS: VCI	BOTTOM CONDITIONS: BOTT RCI	BOTTOM CONDITIONS: GO NO-GO
6	a	Wet	1.22	0.5	Go	.91	1.0	43	5	Go	3.4	0.8	Go	25	80	Go
		Dry		0.3	Go							0.2	Go			Go
7	a	Wet	1.22	0.5	Go	.91	3.0	43	10	Go	3.4	1.8	Go	25	65	Go
		Dry		0.3	Go							0.2	Go			Go
	b	Wet	1.22	1.0	Go	.91	4.0	43	10	Go	3.4	1.0	Go	25	65	Go
		Dry		0.6	Go							0.1	Go			Go
8	a	Wet	1.22	5.0	No-Go	.91		43			3.4					
		Dry		3.0	No-Go											
	b	Wet	1.22	5.0	No-Go	.91		43			3.4					
		Dry		3.0	No-Go											
	c	Wet	1.22	5.5	No-Go	.91		43			3.4					
		Dry		3.5	No-Go											
	d	Wet	1.22	5.0	No-Go	.91		43			3.4					
		Dry		3.0	No-Go											
	e	Wet	1.22	5.5	No-Go	.91		43			3.4					
		Dry		3.5	No-Go											
9	a	Wet	1.22	1.0	Go	.91	4.0	43	15	Go	3.4	1.0	Go	25	50	Go
		Dry		0.6	Go							0.6	Go			Go
	b	Wet	1.22	2.0	No-Go	.91										
		Dry		1.5	No-Go											
	c	Wet	1.22	7.0	No-Go	.91										
		Dry		3.0	No-Go											

Table 5 (Continued).

C. Procedures for Constructing the Complex Overlay.*

Step 1. Decide which type of Complex Overlay is to be prepared, based on the type of CCM map to be produced. If only a wet season CCM map is to be produced, base the Complex Overlay on data for wet season conditions only. (The sample Complex Overlays in this part of the guide are for the wet season.) If a dry season CCM map or both wet and dry season maps are required, base the Complex Overlay on data for dry season conditions.

Step 2.

a. Take the film positive or the lithographic map and aerial photos out of the data base. Place them on a table. Take a clean sheet of frosted mylar, the same size as the film or lithographic map, and place it, frosted side up, on top of the film or litho map. Pin-register them or tape them together. Trace the corner tick marks on the mylar with a black fine-line pencil. Trace the neat line on the mylar lightly with a blue fine-line pencil.

b. Look through the mylar to find the built-up areas. They will appear as clusters of building symbols or sometimes as tinted areas. Using a black fine-line pencil, draw an angular outline that will tightly enclose clusters of building symbols or tinted areas that cover an area larger than this circle .** Color in these outlined areas with a red fine-line pencil as in figure 9. (Aerial photos may be used to update the extent of the built-up areas.)

Step 3.

a. Remove the mylar sheet (which will now be called the Complex Overlay). Pull the Vegetation Factor Overlay (figure 10) out of the Data Base. Put the Complex Overlay on top of the Vegetation Overlay. Pin-register (or match corner ticks and tape the sheets together).

b. Trace all the lines of the Factor Overlay onto the Complex Overlay with a black fine-line pencil. Do not draw any lines through colored areas already on the Complex Overlay. If a new line nearly coincides with a line already drawn on the Complex Overlay, and the space between them is smaller than this ***, do not draw the new line.

---

* Based on procedures devised by A.D. Hastings, Terrain Analysis Center, USAETL.

** Represents an area of .25 km^2 at 1:50,000 scale (dia. 5.6 mm).

*** 100 meters at 1:50,000 (2 mm dia.)

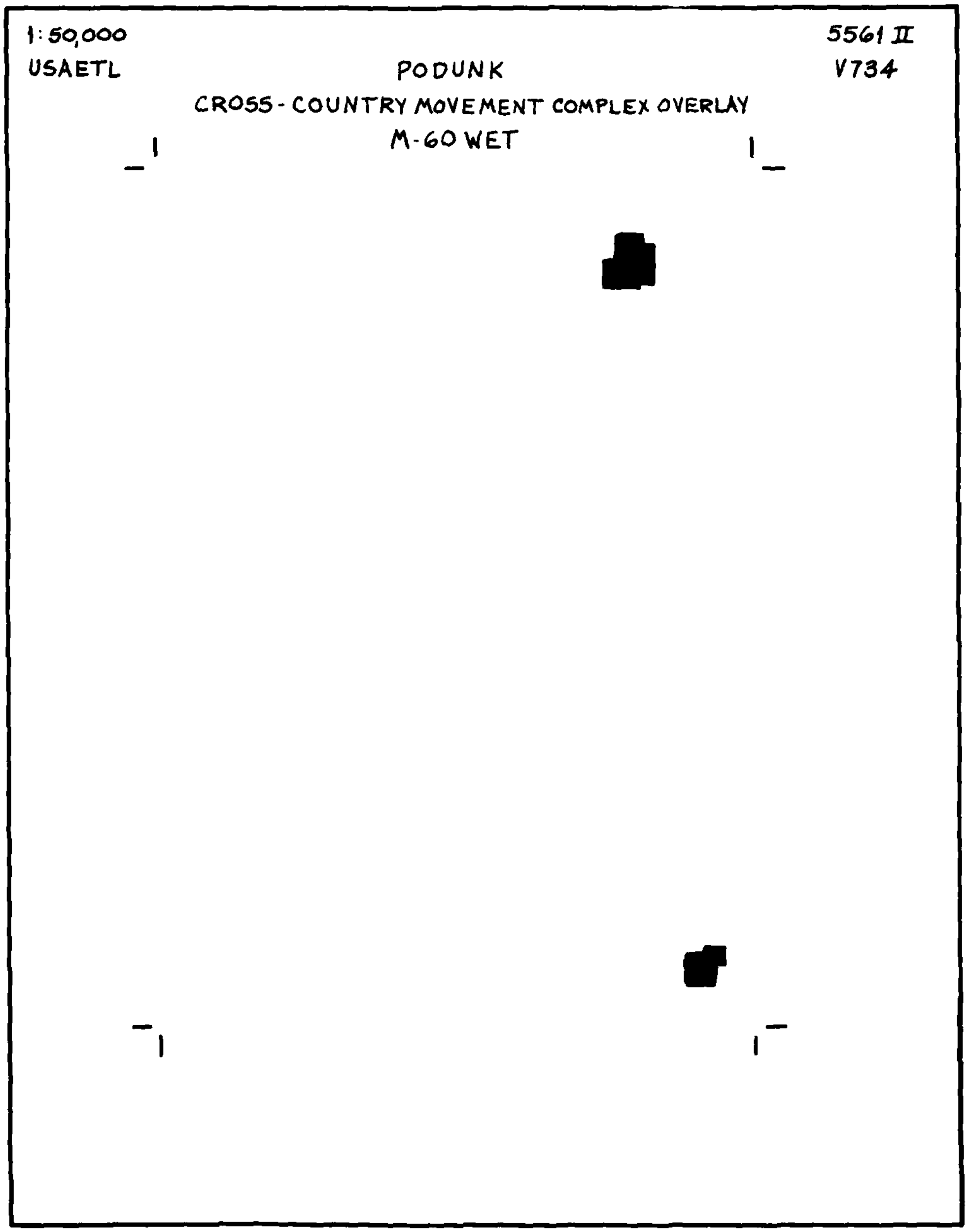


Figure 9. Sample Complex Overlay with Built-Up Areas Added

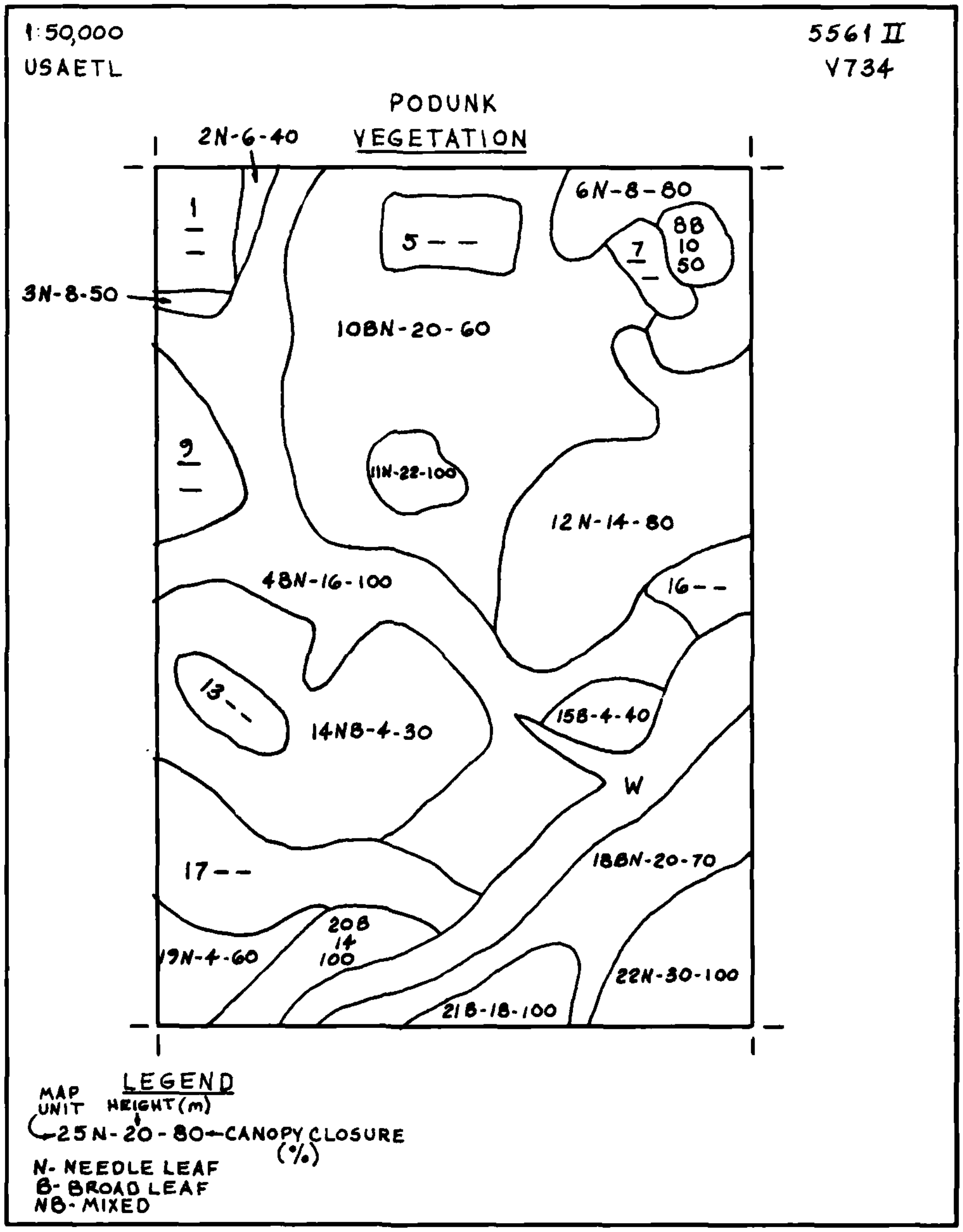


Figure 10. Sample Vegetation Factor Overlay

c. Referring to table 2, note all the vegetation map units that are NO GO. Color these in with a yellow fine-line pencil as in figure 11. Ignore areas smaller than this circle ◯ .

Step 4.

a. Remove the Complex Overlay from the Vegetation Factor Overlay. Put the Vegetation Factor Overlay aside for later use. Pull the Watercourses and Water Bodies Factor Overlay (figure 12) out of the data base. Place the Complex Overlay (which now may have red areas, yellow areas, and black lines on it) on top of the Watercourses and Water Bodies Factor Overlay. Pin-register (or match corner ticks and tape).

b. Trace and color in all drainage features shown as NO GO during the dry season in table 5 with a blue fine-line pencil as shown in figure 13. Trace all drainage features shown as NO GO only during the wet season in red.

Step 5.

a. Remove the Complex Overlay from the Watercourses and Water Bodies Factor Overlay. Put this Factor Overlay aside for later use. Pull the Surface Roughness Factor Overlay (figure 14) out of the data base. Place the Complex Overlay on top of the Surface Roughness Overlay. Pin-register (or match corner ticks and tape).

b. Trace all the lines of the Factor Overlay onto the Complex Overlay with a black fine-line pencil. Do not draw any lines through colored areas already on the Complex Overlay. If a new line nearly coincides with a line already drawn on the Complex Overlay and the space between them is smaller than this circle ◯, do not draw the new line.

c. Look in table 3 and find all the NO GO Surface Roughness map units. Looking through the Complex Overlay, find any NO GO areas on the Surface Roughness Factor Overlay and color them in with a yellow fine-line pencil as in figure 14.

d. Trace all relief obstacles in red.

Step 6.

a. Remove the Complex Overlay from the Surface Roughness Overlay. Put the Surface Roughness Factor Overlay aside for later use. Pull the Slope Factor Overlay (figure 2) out of the data base. Pin-register (or match tick marks and tape).

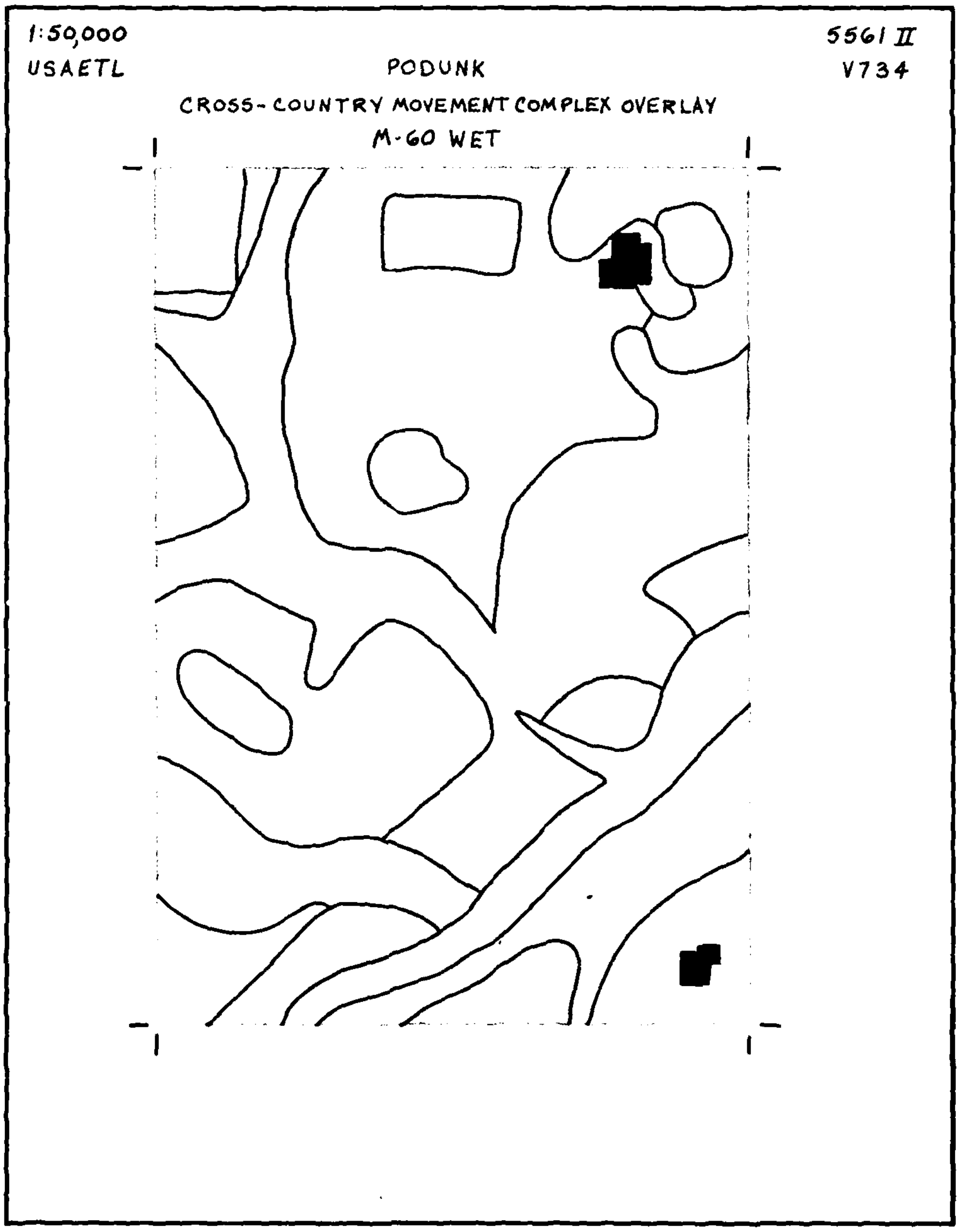


Figure 11. Sample Complex Overlay with Built-Up Areas and Vegetation Added

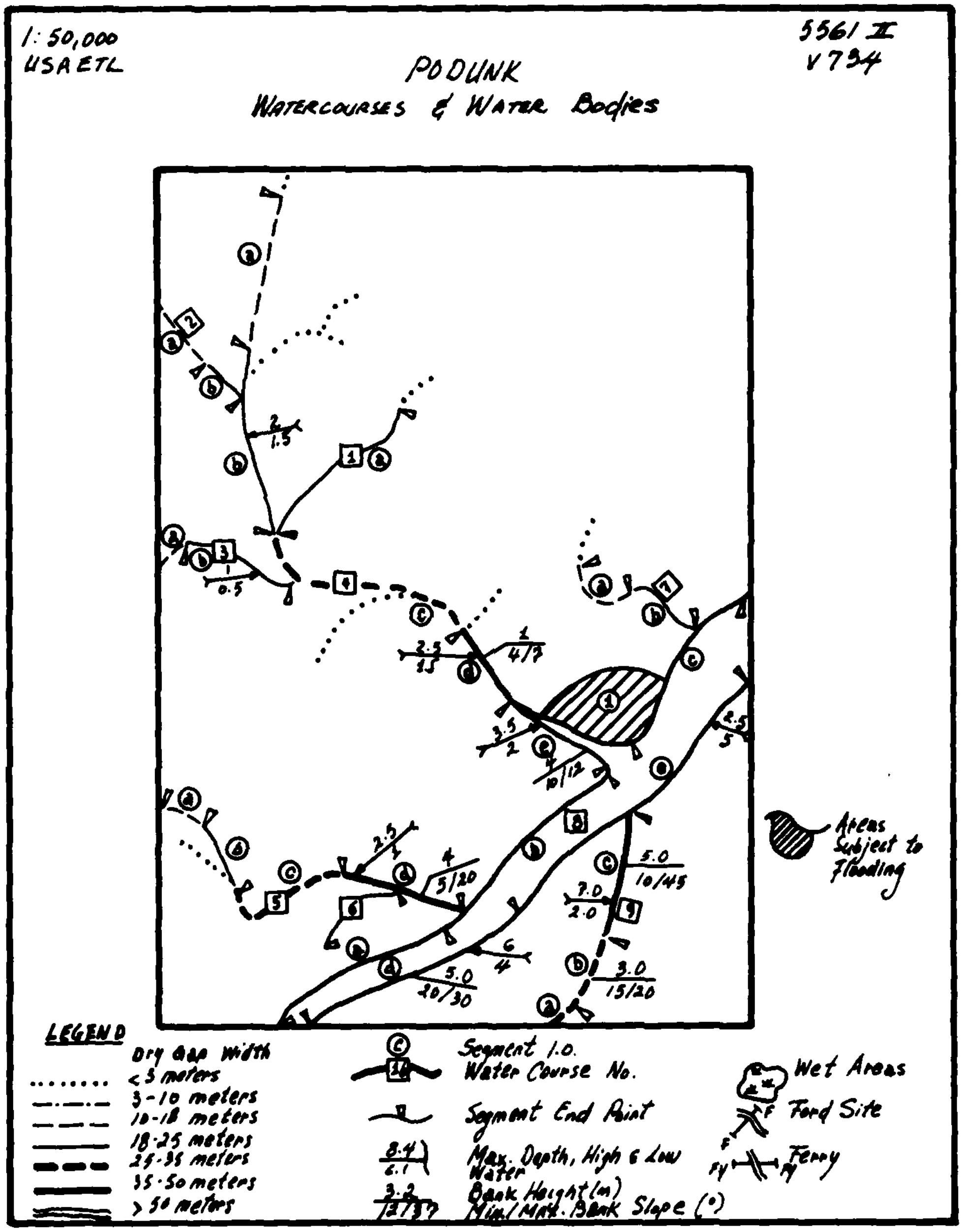


Figure 12. Sample Watercourses and Water Bodies Factor Overlay

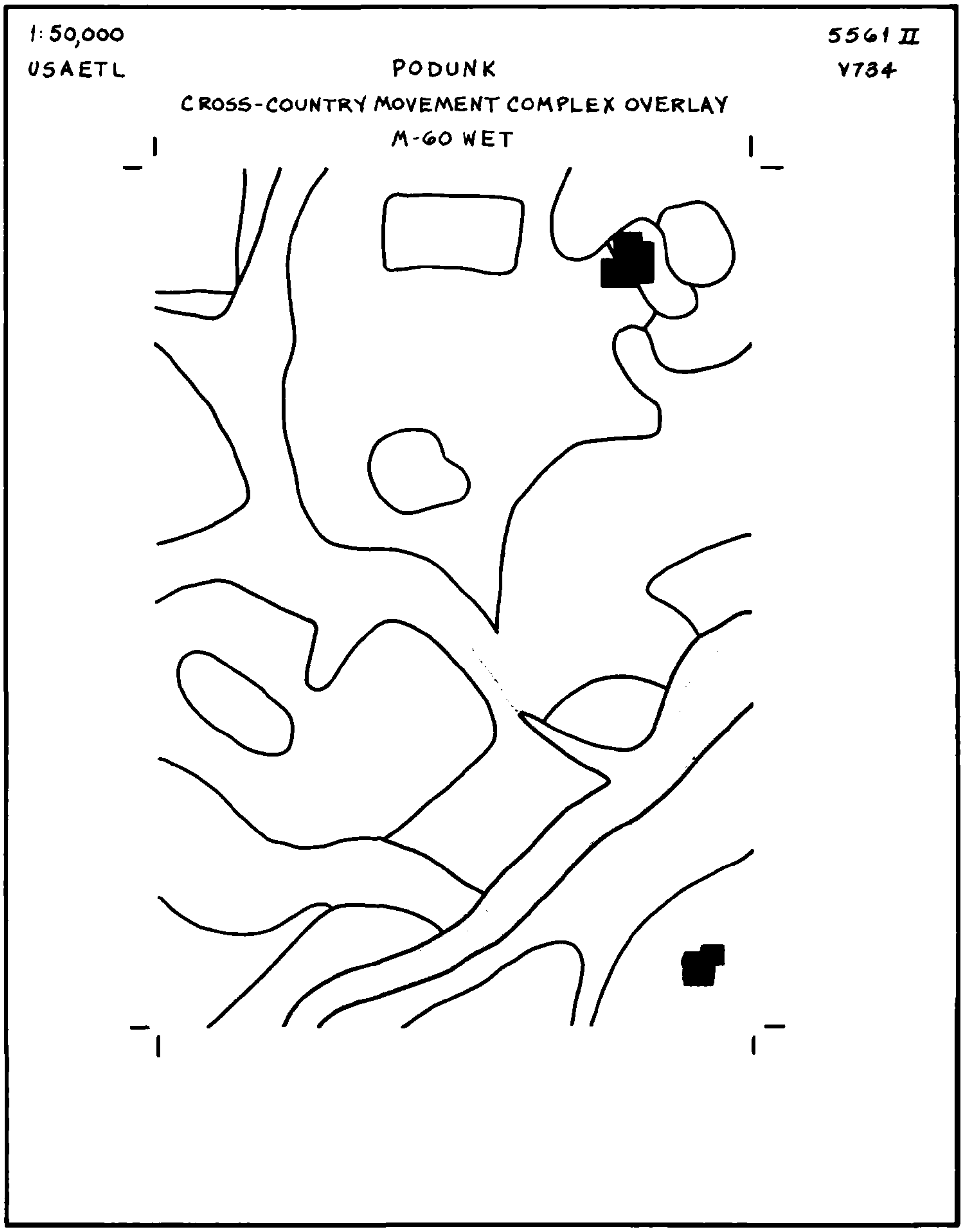


Figure 13. Sample Complex Overlay with Built-Up Areas, Vegetation, and Watercourses Added

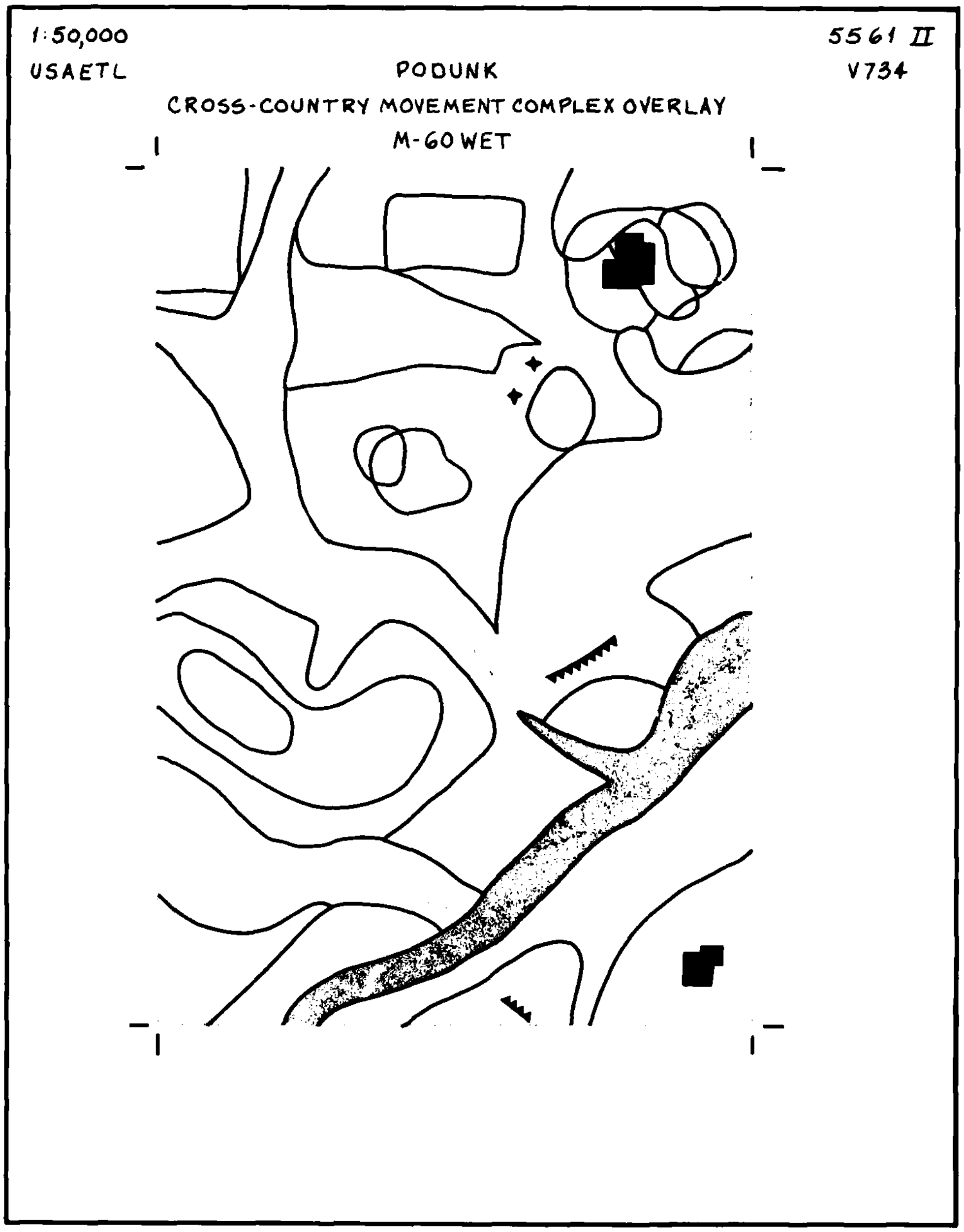


Figure 14. Sample Complex Overlay with Built-Up Areas, Vegetation, Watercourses, and Surface Roughness Added

b. Trace all the lines on the Factor Overlay onto the Complex Overlay with a black fine-line pencil. Do not draw any lines through colored areas already on the Complex Overlay. If a new line nearly coincides with a line already drawn on the Complex Overlay and the space between them is smaller than this circle◯, do not draw the new line.

c. Look in table 1 and find all the NO GO slope map units for the vehicle under consideration. Find these NO GO areas on the Complex Overlay. Color them in with a yellow fine-line pencil as in figure 15.

Step 7.

a. Remove the Complex Overlay from the Slope Factor Overlay. Put the Slope Factor Overlay aside for later use. Pull the Soil Factor Overlay (figure 16) out of the data base. Pin-register (or match corner tick marks and tape).

b. Trace all the lines on the Factor Overlay onto the Complex Overlay with a black fine-line pencil. Do not draw any lines through colored areas already on the Complex Overlay. If a new line nearly coincides with a line already drawn on the Complex Overlay and the space between them is smaller than this circle◯, do not draw the new line.

c. Look in table 4 and find all the NO GO soils for the season (wet or dry) being considered. Find these NO GO areas that appear on the overlay. Color them in with a yellow fine-line pencil as in figure 17.

Step 8.

a. Remove the Complex Overlay from the Soil Factor Overlay. Put the Soil Factor Overlay aside. The Complex Overlay now has many uncolored, irregularly shaped and sized areas formed by all the intersecting black lines drawn on it.

b. Starting in the upper left corner of the Complex Overlay, number these uncolored areas from left to right, consecutively from 1 to 99, in such a way as to number a rectangular portion of the sheet (figure 18).

c. Draw a heavy black pencil line around the border of the large rectangular area. This area is now Sector A. Label the sector by putting a letter A in a conspicuous spot, as in figure 18.

Note that figure 18 represents only a portion of a map sheet and therefore has only one lettered sector. Most Complex Overlays will have several hundred numbered areas and several sectors as shown in the diagram below.

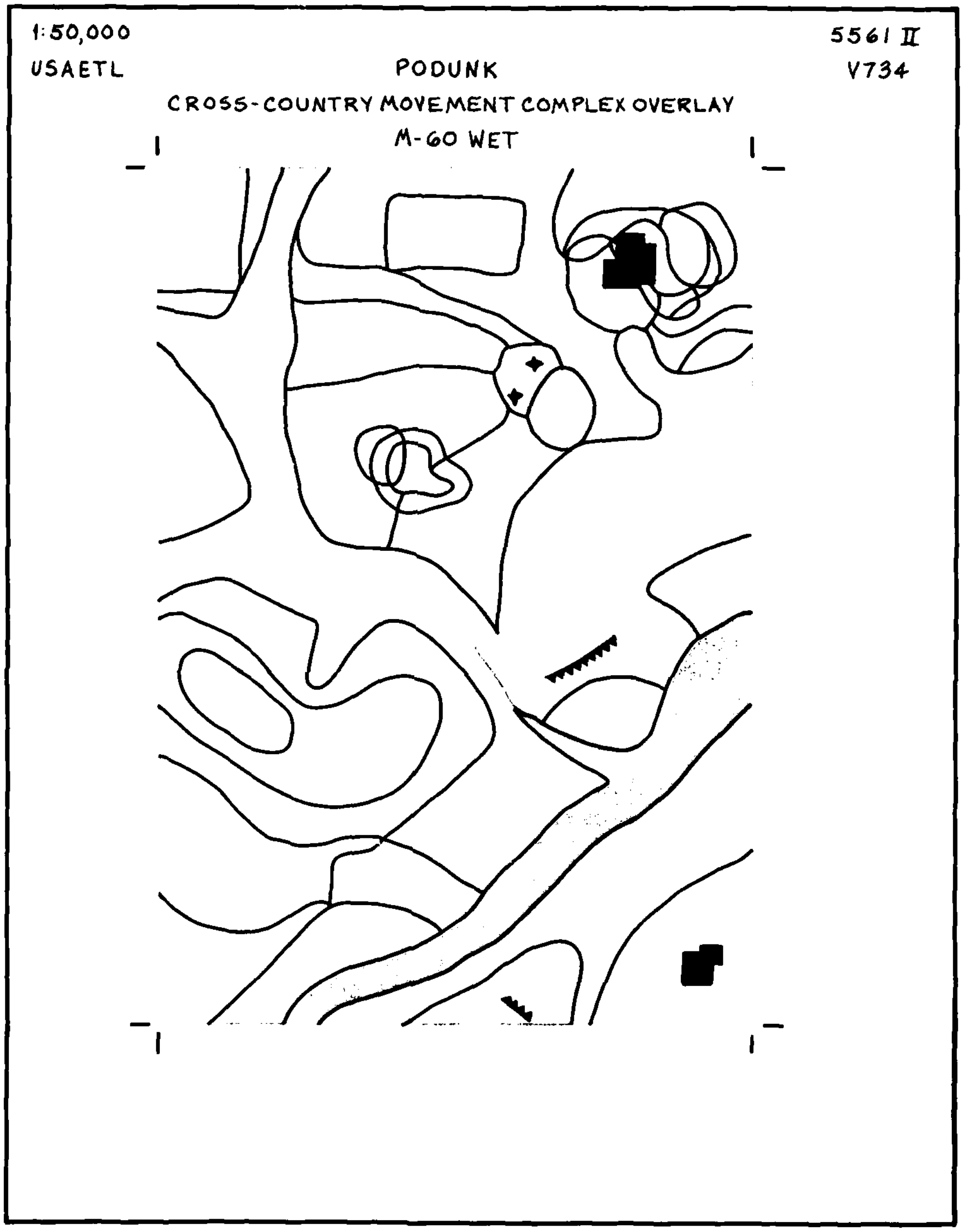


Figure 15. Sample Complex Overlay with Built-Up Areas, Vegetation, Watercourses, Surface Roughness, and Slope Added

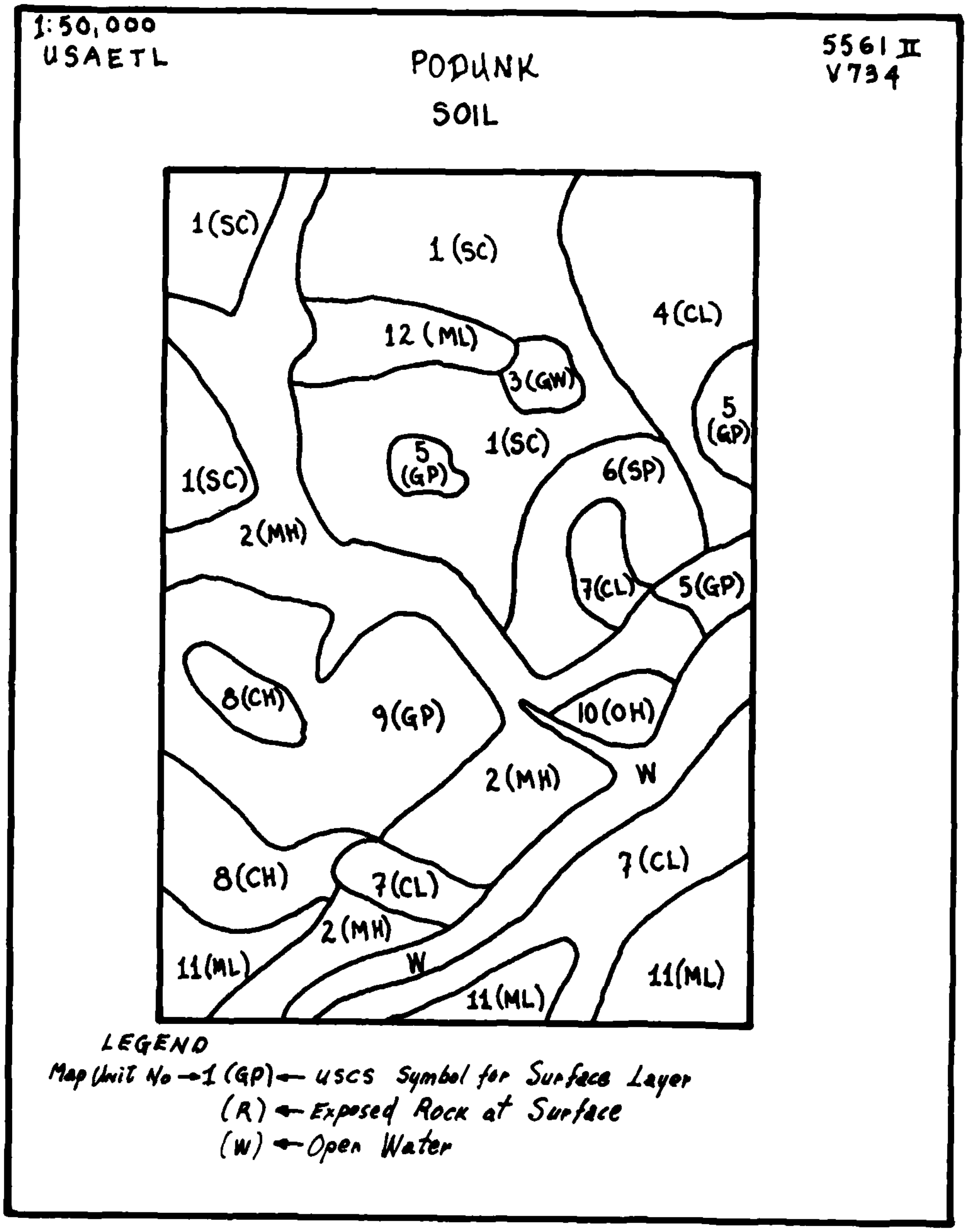


Figure 16. Sample Soil Factor Overlay

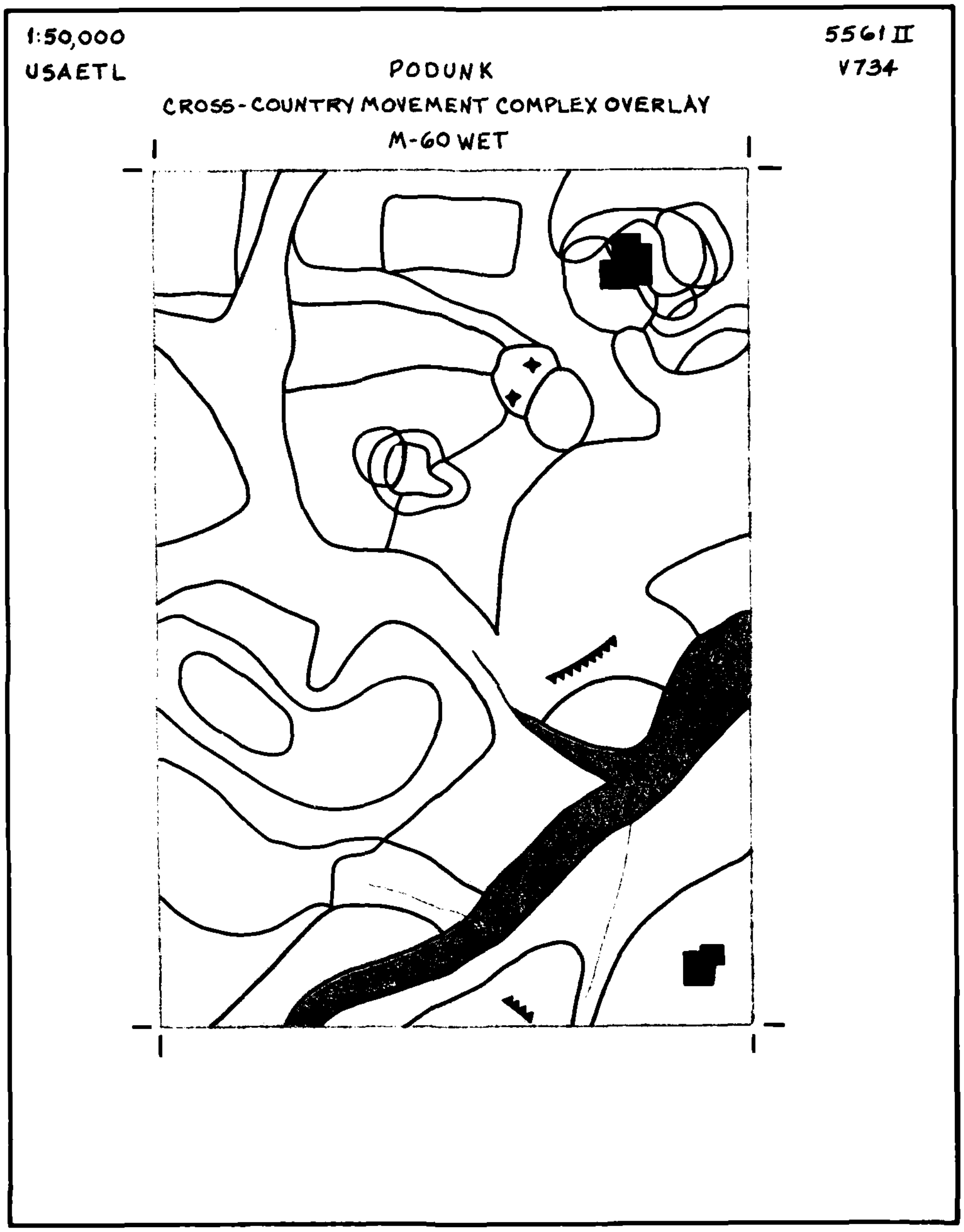


Figure 17. Sample Complex Overlay with Built-Up Areas, Vegetation, Watercourses, Surface Roughness, Slope, and Soil-Added

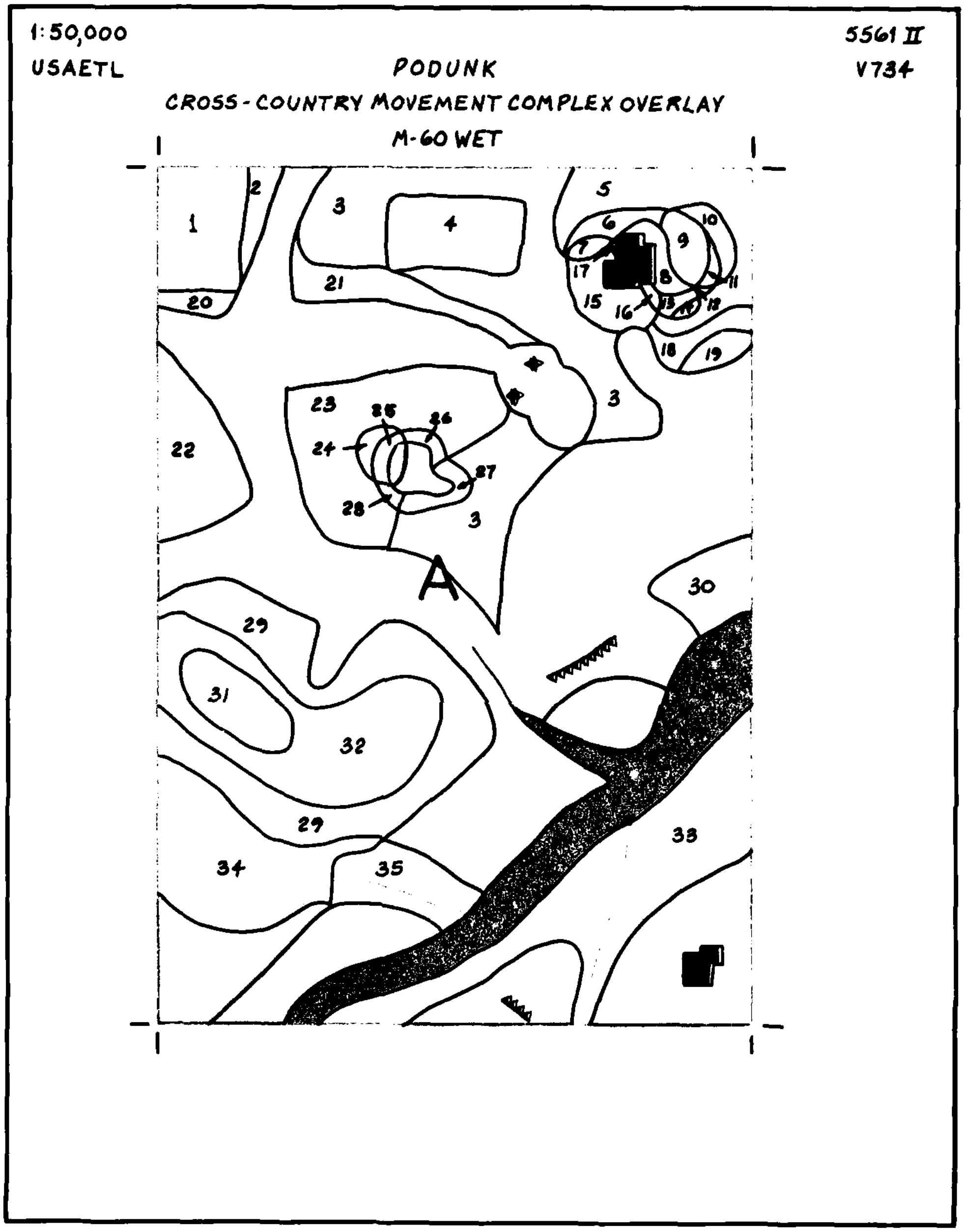
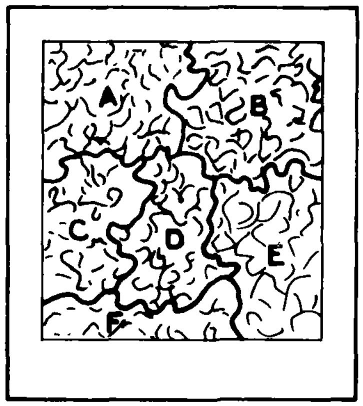


Figure 18. Sample Completed Complex Overlay with Area Numbers Added

d. Repeat the numbering and sectoring process until the overlay is covered. (The last sector may have less then 99 areas in it.) Label the sectors left to right, top to bottom, alphabetically, A - Z (figure 18 and below).



Lettered Sectors

D. Procedures for Computing Speeds.

Step 1. On a separate piece of paper prepare a Speed Prediction Tabulation Sheet for each sector like that in table 6.

Step 2.

a. Retrieve the Slope Factor Overlay. Place the Complex Overlay on top of the Slope Factor Overlay (figure 2). Register.

b. Go to Sector A, Area 1. Look through the Complex Overlay, (or pick up the corner) to see what slope map unit lies under Area 1. * Record this map unit on the Speed Prediction Tabulation Sheet #1 on the row for Area 1 under the left slope column.

c. Go to table 1 and find the S_1 Factor that corresponds to the slope map unit for Area 1. Record this number on the row for Area 1 under the right slope column.

d. Repeat steps b and c until all numbered Areas in Sector A are completed. (If it is discovered that an area was mistakenly not given a number, at this time simply assign it with the number of its left neighboring area plus a small letter, e.g. 1a. Insert 1a between 1 and 2 on the Speed Prediction Tabulation Sheet #1.)

e. Repeat steps b and c for all remaining sectors until all the numbered areas on the overlay have been given S_1 values.

Step 3.

a. Remove the Slope Factor Overlay from the Complex Overlay. Put the Slope Factor Overlay back in the data base.

b. Retrieve the Vegetation Factor Overlay. Place the Complex Overlay on top of the Vegetation Factor Overlay. Register.

c. Go to Sector A, Area 1. Look through the Complex Overlay, (or pick up the corner) to see what Vegetation Map unit lies under Area 1. Record this map unit on the Speed Prediction Tabulation Sheet on the row for Area 1 under the left vegetation column.

---

* In some cases, a single area of the Complex Overlay may lie over parts of two map units on the factor overlay because of omission of lines that nearly coincide during the complexing phase. Use the factor map unit that occupies the greater portion of the complex area.

SPEED PREDICTION TABULATION SHEET #1

Sector A																
Area	SLOPE		VEGETATION				SURFACE ROUGHNESS			SOIL					CCM - Dry	CCM - Wet
	Map Unit	S_1	Map Unit	F_1	F_2	S_2	Map Unit	F_3	S_3	Map Unit	F_{4D}	F_{4W}	S_{4D}	S_{4W}	Map Unit	Map Unit
1	B	40	1	–	–	40	4	.5	20	1	1	.55	20	11.0	3	4
2	B	40	2	1.0		40	4	.5	20	1	1	.55	20	11.0	3	4
3	B	40	10	1.0		40	4	.5	20	1	1	.55	20	11.0	3	4
4	B	40	5	–	–	40	4	.5	20	1	1	.55	20	11.0	3	4
5	C	24	6	.34		8.16	4	.5	4.8	4	1	.33	4.8	1.6	5	5
6	C	24	6	.34		8.16	1	1	8.16	4	1	.33	8.16	2.7	4	5
7	A	45.6	6	.34		15.5	1	1	15.5	4	1	.33	15.5	5.1	4	5
8	B	40	7	–	–	40	1	1	40	4	1	.33	40	13.2	1	4
9	B	40	8	.40		16	1	1	16	4	1	.33	.16	5.3	4	5
10	C	24	8	.40		9.6	4	.5	4.8	4	1	.33	4.8	1.6	5	5
11	C	24	8	.40		9.6	1	1	9.6	4	1	.33	9.6	3.2	4	5
12	C	24	6	.34		8.16	1	1	8.16	4	1	.33	8.16	2.7	4	5
13	C	24	7	–	–	24	1	1	24	4	1	.33	24	8.0	3	4
14	C	24	7	–	–	24	4	.5	12	4	1	.33	12	4.0	4	5
15	A	45.6	10	1		45.6	1	1	45.6	4	1	.33	45.6	15	1	4
16	A	45.6	7	–	–	45.6	1	1	45.6	4	1	.33	45.6	15	1	4
17	A	45.6	7	–	–	45.6	1	1	45.6	4	1	.33	45.6	15	1	4
18	D	12	6	.34		4.0	4	.5	2.0	4	1	.33	2.0	.66	5	5
19	D	12	6	.34		4.0	6	.2	0.8	4	1	.33	0.8	.26	5	6
20	B	40	3	.52		20.8	4	.5	10.4	1	1	.55	10.4	5.7	4	5
21	C	24	10	1		24	3	.9	21.6	1	1	.55	21.6	11.9	3	4
22	B	40	9	–	–	40	2	1	40	1	1	.55	40	22	1	3
23	D	12	10	1		12	4	.5	6	1	1	.55	6	3.3	5	5
24	D	12	10	1		12	7	.1	1.2	1	1	.55	1.2	0.7	5	5
25	D	12	11	.17		2.0	4	.5	1	5	1	1	1	1	5	5
26	D	12	11	.17		2.0	4	.5	1	5	1	1	1	1	5	5
27	B	40	11	.17		6.8	4	.5	3.4	5	1	1	3.4	3.4	5	5
28	D	12	11	.17		2.0	4	.5	1	1	1	.55	1	.55	5	5
29	D	12	14	1.		12	6	.2	2.4	9	1	1.0	2.4	2.4	5	5
30	B	40	16	–	–	40	2	1	40	5	1	1.0	40	40	1	1
31	A	45.6	13	–	–	45.6	4	.5	22.8	8	1	.88	22.8	20	3	3
32	C	24	14	1.		24	4	.5	12	9	1	1.0	12	12	4	4
33	B	40	18	1.		40	1	1	40	7	1	.33	40	13.2	1	4
34	B	40	17	–	–	40	1	1	40	8	1	.88	40	35.2	1	2
35	A	45.6	17	–	–	45.6	1	1	45.6	7	1	.33	45.6	15	1	4

Table 6. Sample Speed Prediction Tabulation Sheet #1

d. Look in table 2 and find F_1 or F_2 that corresponds to the vegetation map unit under Area 1. Record this number on the row for Area 1 under the right vegetation column. (If there is no F_1 or F_2 value, record a dash).

e. Find S_2 by multiplying by F_1 or F_2. Record the value for S_2 on the row for Area 1 under the S_2 column. (If there is no F_1 or F_2 value, then S_2 equals S_1. Record the S_1 value under the S_2 column).

f. Repeat steps c, d, and e until all numbered areas in Sector A are given vegetation numbers on the tabulation sheet.

g. Repeat steps c, d, and e for all remaining sectors until all numbered areas on the overlay have been given S_2 values on the tabulation sheet.

Step 4.

a. Remove the Vegetation Factor Overlay and return it to the data base.

b. Retrieve the Surface Roughness Factor Overlay. Place the Complex Overlay on top of the Surface Roughness Factor Overlay and register.

c. Go to Sector A, Area 1. Look through the Complex Overlay (or pick up the corner) to see what Surface Roughness map unit lies under Area 1. Record this map unit on the Speed Prediction Tabulation Sheet #1 on the row for Area 1 and under the left surface roughness column.

d. Look in table 3 and find F_3 that corresponds to the Surface Roughness map unit under Area 1. Record this number on the row for Area 1 under the right Surface Roughness column.

e. Multiply F_3 by S_2 to find S_3, i.e., $S_3 = F_3 \times S_2$. Record the value for S_3 in the row for Area 1 under the S_3 column.

f. Repeat steps c, d, and e until all areas in Sector A have been given S_3 value numbers.

g. Repeat steps c, d, and e for all remaining sectors.

Step 5.

a. Remove the Surface Roughness Factor Overlay and put it back in the data base.

b. Retrieve the Soil Factor Overlay and place the Complex Overlay on top of it. Register.

c. Go to Sector A, Area 1. Look through the Complex Overlay (or pick up the corner) to see what soil map unit lies under Area 1. Record this map unit on the Speed Prediction Tabulation Sheet #1 on the row for Area 1 and under the left soil column.

d. Look in table 4 and find F_{4D} that corresponds to the soil map unit under Area 1. Record this number on the Speed Prediction Tabulation Sheet #1 (table 6) on the row for Area 1 under the right soil column. Then do the same for F_{4W} if a wet season CCM map is required.

e. Multiply F_{4D} by S_3 to find S_{4D}, i.e., $S_{4D} = S_3 \times F_{4D}$. Round off the answer to the nearest whole number, e.g. 8.50 = 9 and 8.49 = 8. Record the value for S_{4D} in the row for Area 1 under the S_{4D} column. Then do the same for F_{4W} to find S_{4W}.

f. Repeat steps c, d, and e until all areas in Sector A have been given S_{4D} and/or S_{4W} values.

g. Repeat steps c, d, and e for all remaining sectors.

Step 6. Categorize the S_{4D} and S_{4W} values into CCM map units according to table 7, and record in the CCM map unit columns of the Speed Prediction Tabulation Sheet #1 (table 6).

Table 7. Categoires for Speeds and CCM Map Units

SPEEDS (kph)	CLASS	CCM MAP UNIT #
>40	Excellent	1
33-40	Very Good	2
17-32	Good	3
8-16	Fair	4
.5-7	Poor	5
$<.5$	NO GO	6
Built-up Area	NO GO	7

Step 7.

a. Place a clean sheet of frosted mylar on the CCM dry season Complex Overlay. Pin-register (or tape) the sheets together. Trace the corner tick marks with a black fine-line pencil. Trace the neat line lightly with a blue fine-line pencil. If a CCM dry season map is desired, continue to Step 7b. If a CCM wet season map is desired, go NOW to Step 8.

b. Trace the outline of all red areas with a black pencil. Label them with the map unit number 7.

c. Trace all dry season water obstacles with a black outline and a blue fill. Single line streams may be all blue.

d. Over each numbered area showing through the mylar, write the dry season CCM map unit number for that area.

e. Trace the outlines of all numbered areas with a black pencil, omitting lines between areas with the same map unit number.

f. Trace the outlines of all yellow areas, omitting lines between adjacent yellow areas. Label them with the map unit number 6.

g. Trace with a red fine-line pencil all relief obstacles.

h. Match all four sides of the last sheet of mylar, now called the CCM dry season maunscript with the completed manuscripts for the adjoining map sheets. Make sure that continuing map units do, indeed, continue onto the next sheet.

i. Place the legend in the appropriate place on the CCM manuscript as indicated in figure 19.

Step 8.

a. Place a clean sheet of mylar on top of the CCM Complex Overlay. Trace corner ticks with a black fine-line pencil, and neat lines with a blue fine-line pencil.

b. Trace the outline of all red areas in black. Label them with the map unit number 7.

c. Trace all wet season water obstacles with a black outline and a blue fill. Single line streams will be all blue.

d. Over each numbered area showing through the mylar, write the CCM wet season map unit number for that area.

e. Trace the outlines of each numbered area in black, omitting lines between areas with the same map unit number.

f. Trace the outlines of all yellow areas, omitting lines between adjacent areas. Label them with the map unit number 6.

g. Trace all relief obstacles in red.

Step 9. Match all four sides of the last sheet of mylar, now called the CCM wet season manuscript, with the completed CCM wet season manuscripts for the four adjoining map sheets. Make sure that continuing map units do, indeed, continue onto the next sheet.

Step 10. Place the legend in the appropriate place on the CCM manuscript as indicated in figure 19.

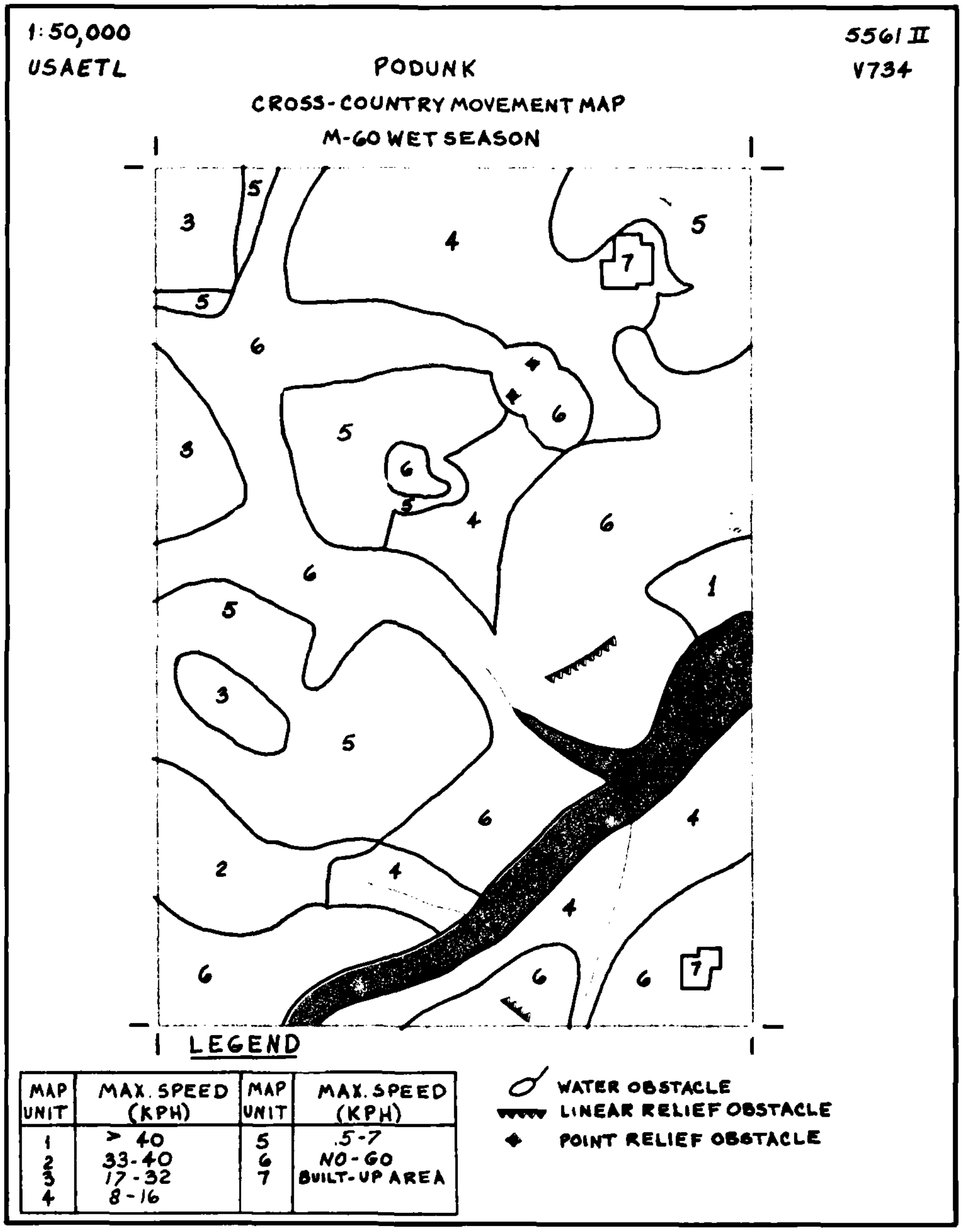


Figure 19. Sample Completed CCM Manuscript

III. Mathematical Model Approach Using Programable Calculator (HP-97)*

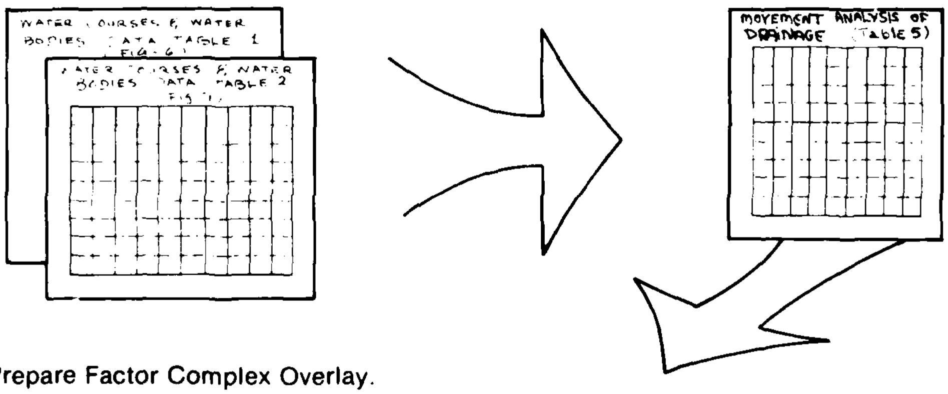
A. Introduction

The mathematical model shown in figure 1, which yields an expected maximum vehicle speed for specific terrain, can be put into a programable calculator, such as the HP-97 (see program flow chart, table 14). In the next section, instructions are given for using the programable calculator in the synthesis process.

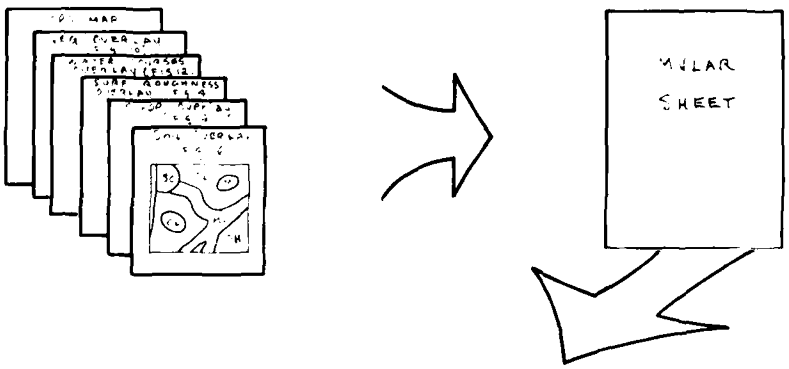
The following diagram summarizes and illustrates the steps in the next section:

Flow Diagram

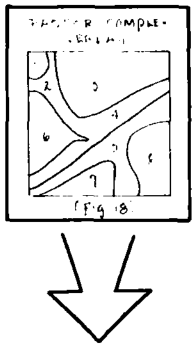
Do Movement Analysis of Drainage.



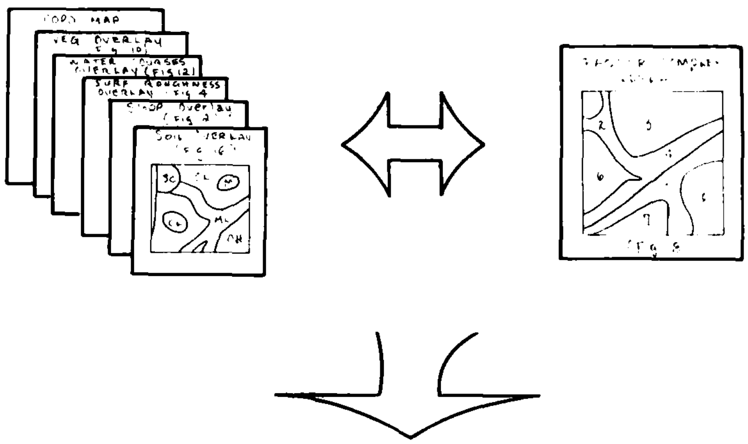
Prepare Factor Complex Overlay.

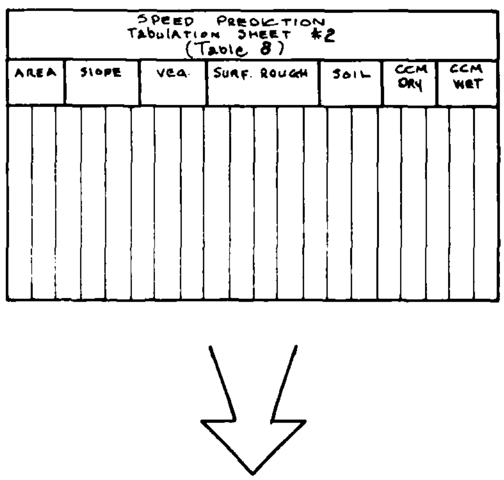


* Other programable calculators may be used.

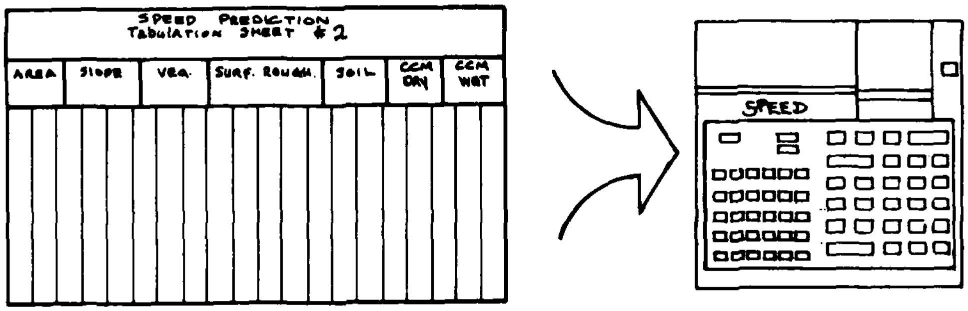


Prepare Speed Prediction Tabulation Sheet #2 and Enter Data onto It from Factor Overlays and Factor Complex Overlay.

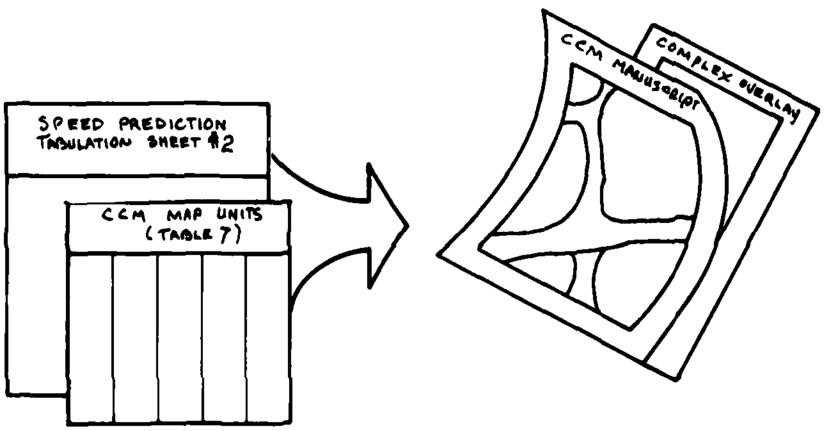




Program the Calculator, Enter Data From Speed Prediction Tabulation Sheet #2, Calculate Speeds.



Assign Speed Categories to Each Map Unit, Trace Complex Overlay, and Complete CCM Manuscript.



B. Procedures

Step 1. Perform a movement analysis of drainage features as required in section II B, Step 10.

Step 2. Prepare a Factor Complex Overlay as required in section II. Show built-up areas and drainage obstacles, but do not show other NO GO areas. It is not necessary to compute S_1 or any of the F values at this time.

Step 3. On a separate sheet of paper, prepare a Speed Prediction Tabulation Sheet #2, as in table 8.

Step 4.

a. Retrieve the Slope Factor Overlay. Place the Complex Overlay on top of the Slope Factor Overlay. Register.

b. Go to Sector A, Area 1 on the Complex Overlay. Look through the Complex Overlay (or pick up the corner) to see what slope map unit lies under Area 1. Record this map unit on the Speed Prediciton Tabulation Sheet #2 on the row for Area 1 under the left Slope column. Under the right Slope column, labeled "value", write the highest value for that map unit. For example, slope map unit A may include slopes from 0 to 3 percent. In this case, record A in the left Slope column, and 3 in the right Slope column as in table 8.

c. Repeat Step b above for the remaining areas in Sector A.

d. Repeat Step b and c above for the remaining sectors on the Complex Overlay.

Step 5.

a. Remove the Slope Factor Overlay from the Complex Overlay. Put the Slope Factor Overlay back in the data base.

b. Retrieve the Vegetation Factor Overlay and Vegetation Data Table 1. Place the Complex Overlay on top of the Vegetation Factor Overlay. Register.

c. Go to Sector A, Area 1. Look through the Complex Overlay, (or pick up a corner) to see what Vegetation Map Unit lies under Area 1. Record this map unit in the row for Area 1 under the left Vegetation column on the Speed Prediction Tabulation Sheet #2. Look on the Vegetation Data Table 1 and find the stem spacing value and the mean stem diameter value for that map unit. Convert the stem diameter value from centimeters to meters, i.e. 18 cm = .18 m. Record these values in their proper columns in the row for Area 1 on the Speed Prediction Tabulation Sheet #2, table 8.

SECTOR A

Area Number	Slope		Vegetation			Surface Roughness		Soil			Speed		CCM Map Unit Number	
	Map Unit	%	Map Unit	Stem Spacing (m)	Stem Diameter (m)	Map Unit	Factor	Map Unit	RCI Dry	RCI Wet	Dry (Kph)	Wet (Kph)	Dry	Wet
1	B	10	1	(30)	(5)	4	.5	1	130	50	20	11	3	4
2	B	10	2	11.1	.21	4	.5	1	130	50	20	11	3	4
3	B	10	10	15.7	.60	4	.5	1	130	50	20	11	3	4
4	B	10	5			4	.5	1	130	50	20	11	3	4
5	C	30	6	6.4	.26	4	.5	4	125	40	4	1	5	5
6	C	30	6	6.4	.26	1	1	4	125	40	8	3	5	5
7	A	3	6	6.4	.26	1	1	4	125	40	16	5	4	5
8	B	10	7	(30)	(5)	1	1	4	125	40	40	13	1	4
9	B	10	8	7.0	.40	1	1	4	125	40	16	5	4	5
10	C	30	8	7.0	.40	4	.5	4	125	40	5	2	5	5
11	C	30	8	7.0	.40	1	1	4	125	40	10	3	4	5
12	C	30	6	6.4	.26	1	1	4	125	40	8	3	4	5
13	C	30	7	(30)	(5)	1	1	4	125	40	24	8	3	4
14	C	30	7	(30)	(5)	4	.5	4	125	40	12	4	4	5
15	A	3	10	15.7	.60	1	1	4	125	40	46	15	1	4
16	A	3	7	(30)	(5)	1	1	4	125	40	46	15	1	4
17	A	3	7	(30)	(5)	1	1	4	125	40	46	15	1	4
18	D	45	6	6.4	.26	4	.5	4	125	40	2	1	5	5
19	D	45	6	6.4	.26	6	.2	4	125	40	1	0.28	5	6
20	B	10	3	7.6	.25	4	.5	1	130	50	10	6	4	5
21	C	30	10	15.7	.60	3	.9	1	130	50	22	12	3	4
22	B	10	9	(30)	(5)	2	1	1	130	50	40	22	2	3

Table 8. Sample Speed Prediction Tabulation Sheet #2 for M60 Tank

(If there is no stem spacing or stem diameter value owing to the absence of trees, record a value of 30 for stem spacing and 5 for stem diameter on Speed Prediction Tabulation Sheet #2.)

d. Repeat Step 5c for all areas in Sector A, and then for all sectors on the Complex Overlay.

Step 6.

a. Remove the Vegetation Factor Overlay and put it back in the data base.

b. Retrieve the Soil Factor Overlay and place the Complex Overlay on top of it.

c. Go to Sector A, Area 1. Look through the Complex Overlay (or pick up a corner) to see what soil map unit lies under Area 1. Record this map unit on the Speed Prediction Tabulation Sheet #2 on the row for Area 1 in the proper column under Soil. Find this map unit on the Soil Data Table and record the values for RCI_D, and RCI_W on the Speed Prediction Tabulation Sheet #2 in the appropriate columns under Soil.

d. Repeat 6c for all areas in Sector A, and then for all areas in each of the other sectors on the Complex Overlay.

e. Remove the Soil Factor Overlay and put it back in the data base.

Step 7.

a. Take the Program Card (for the vehicle concerned) out of the Program Card Packet (figure 20). Handle the Program Card with care; do not fold, spindle, or mutilate. If there is no Program Card for the vehicle concerned in the Packet, go NOW to Step 12.

b. Slide the OFF-ON button on the HP-97 to ON (figure 21).

c. Slide the PRGM-RUN button to RUN (figure 21).

d. Slide the MAN-TRACE-NORM button to MAN (figure 21).

e. Hold the Program Card with the white side up, and insert side 1 (figure 20) into the card reader slot (figure 21) as shown in figure 22. When it is partially into the slot, the machine will take the card. After it is fed automatically through the machine, the card will emerge from a slot at the back of the machine.

Figure 20. CCM Program Card For the XM-1 and M-60 Tanks

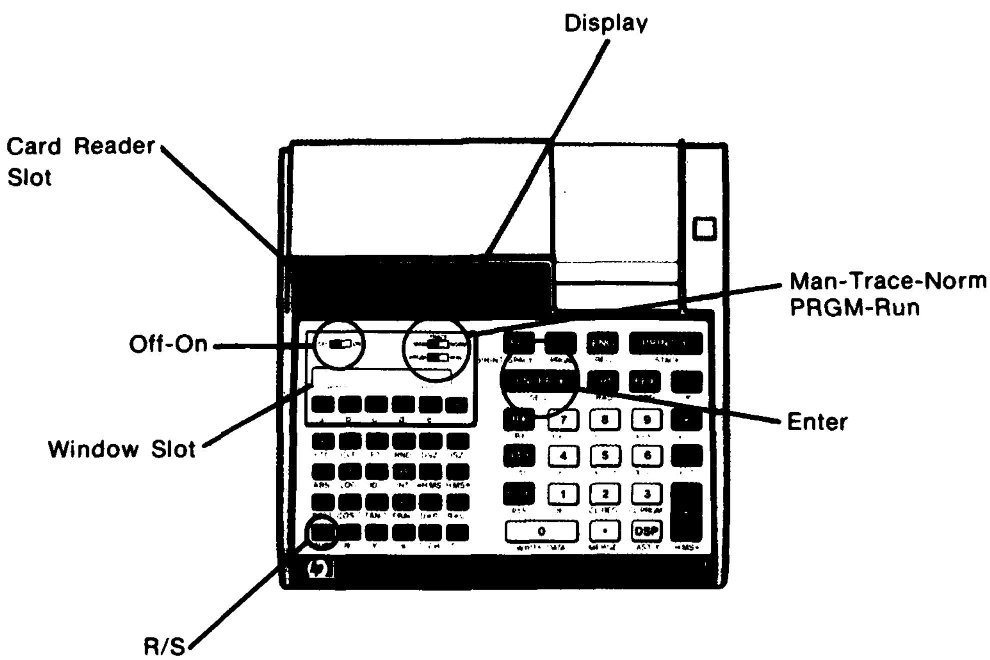


Figure 21. HP-97 Calculator (Source: The HP-97 Programmable Printing Calculator Owner's Handbook and Programming Guide, 1977)

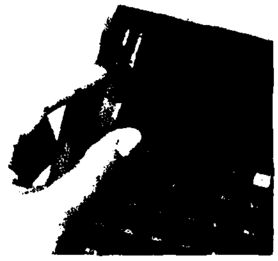


Figure 22. Inserting Program Card Into Card Reader Slot (Source: The HP-97 Programmable Printing Calculator Owner's Handbook and Programming Guide, 1977)

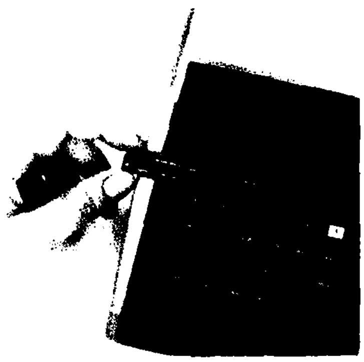


Figure 23. Inserting Program Card Into Window Slot (Source: The HP-97 Programmable Printing Calculator Owner's Handbook and Programming Guide, 1977)

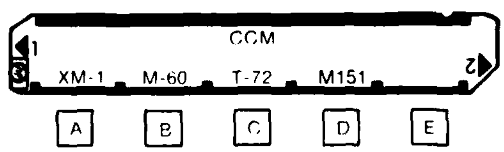


Figure 24. Specific Vehicles Printed on the Program Card

f. When the card appears and after the feed motor stops running, take the card out of the calculator.

g. Insert side 2 into the card reader slot.

h. After the card appears at the back, slide it carefully into the window slot (figure 21) as shown in figure 23.

Step 8.

a. If a CCM dry season map is required, complete Step 8. If a CCM wet season map is required, go NOW to Step 11.

b. Press the letter (A, B, C, or D) that lies under the vehicle of interest printed on the Program Card (figure 24). The display window will flash for a few moments and then a value will appear. Ignore this value.

c. Starting with Sector A, Area 1, read the slope value from the Speed Prediction Tabulation Sheet #2 (table 8). Enter this value into the calculator by pressing the appropriate number keys.

d. Press the R/S button. The display window will flash and a value will appear. Ignore this value.

e. Read the mean stem diameter for Sector A, Area 1, from the Speed Prediction Tabulation Sheet #2 (table 8). Enter this value by pressing the appropriate number keys.

f. Press the R/S button. A value will appear in the display window. Ignore this value.

g. Read the stem spacing value for Sector A, Area 1 from the Speed Prediction Tabulation Sheet #2 (table 8). Enter this value by pressing the appropriate number keys.

h. Press the R/S button. The display will flash until a value appears. Ignore this value.

i. Read the surface roughness factor for Sector A, Area 1 from the Speed Prediction Tabulation Sheet #2 (table 8). Enter this value by pressing the appropriate number keys.

j. Press the R/S button. The display will flash until a value appears. Ignore this value.

k. Read the RCI-DRY value for Sector A, Area 1 from Speed Prediction Tabulation Sheet #2 (table 8). Enter this value by pressing the appropriate number keys.

l. Press the R/S button.

m. The value appearing in the display is the speed for dry conditions. Values .5 and greater are automatically rounded-off to the nearest whole number, e.g. .5 would be rounded-off to 1. Values less than .5 appear in the display in scientific notation, e.g. 0.28 would look like 2.800000000 -01. The -01 indicates that the decimal point be moved 1 placed to the left to give .28. The number .28 should be entered on the Speed Prediction Tabulation Sheet #2. Record this value in the DRY SPEED column on the Speed Prediction Tabulation Sheet #2 (table 8).

n. Look in table 7 to determine the dry season CCM map unit number for the above speed. Record this map unit number in the appropriate column on the Speed Prediction Tabulation Sheet #2 (table 8).

o. Repeat Steps 8b through 8n for all areas in all sectors.

Step 9.

a. Place a clean sheet of frosted mylar over the Complex Overlay. Pin-register (or tape) the sheets together. Trace the corner tick marks with a black fine-line pencil. Trace the neat line lightly with a blue fine-line pencil.

b. Using a black fine-line pencil, lightly trace the outlines for each area from the Complex Overlay.

c. Over each area in each sector showing through the mylar, write the dry season CCM map unit number for that area.

d. Trace the drainage obstacles in dark blue.

e. Erase any lines between areas with the same dry season CCM map unit number.

f. Label NO GO areas showing through the mylar with the dry season CCM map unit number 6.

g. Label red areas showing through the mylar with the dry season CCM map unit number 7.

Step 10. Add the legend and other marginal information as shown in figure 19.

Step 11.

a. If a CCM wet season map is required, complete Step 11. If not, ignore Step 11.

b. Follow Part III, Steps 8b through 8j above.

c. Read the RCI-WET value for Area 1, Sector A from the Speed Prediction Tabulation Sheet #2 (table 8). Enter this value into the calculator by pressing the appropriate number keys.

d. Follow Part III, Steps 8l through 8n.

e. Repeat III, Steps 11b through 11d for all areas in all sectors.

f. Follow Part III, Steps 9 through 10, substituting "wet season CCM" for "dry season CCM".

Step 12.

a. If these is no Program Card (figure 20) for the vehicle(s)* of interest, and there are no blank cards, proceed with this step. Otherwise, go NOW to Step 13.

b. Make a list of the following vehicle specifications:

Maximum Road Gradability in percent.
Maximum Road Speed in kilometers per hour (kph) or miles per hour (mph).
Vehicle Width in meters.
Maximum Override Diameter in meters at breast height.
Vehicle Cone Index, one pass (VCI_1).
Vehicle Cone Index, 50 passes (VCI_{50}).
Subtract VCI_1 from VCI_{50} (VCI_{50} - VCI_1).

c. Slide the OFF-ON button to ON (figure 21).

d. Slide the MAN-TRACE-NORM button to MAN (figure 21).

e. Slide the PRGM-RUN button to PRGM (figure 21).

---

* Up to four vehicles can be stored on one card.

f. Press the following buttons in the exact order given, substituting vehicle values where indicated.

LBL	
A	Identifies the selected vehicle, e.g. XM-1
3	Width in meters for selected vehicle, e.g. 3.65 for XM-1 (table 9)
.	
6	
5	
STO	
1	
7	Max road speed in kph for selected vehicle, e.g. 71.0 for XM-1 (table 9)
1	
STO	
2	
.	Vehicle override diameter in meters for selected vehicle, e.g. .25 for XM-1 (table 9)
2	
5	

Key	
$\boxed{\text{STO}}$	
$\boxed{3}$	
$\boxed{6}$	Max road gradability in percent for selected vehicle, e.g. 68.7 for XM-1 (table 9)
$\boxed{8}$	
$\boxed{.}$	
$\boxed{7}$	
$\boxed{\text{STO}}$	
$\boxed{4}$	
$\boxed{2}$	VCI_1 value for selected vehicle, e.g. 24 for XM-1 (table 9)
$\boxed{4}$	
$\boxed{\text{STO}}$	
$\boxed{D}$	
$\boxed{3}$	($VCI_{[illegible]}$ - VCI_1) value for selected vehicle, e.g. (56 - 24) = 32 for XM-1 (table 9)
$\boxed{2}$	
$\boxed{\text{STO}}$	
$\boxed{E}$	

GTO	
1	
* LBL	
B	Identifies another vehicle, e.g. M60A1
3	Width of above vehicle in meters, e.g. 3.63 for M60A1 (table 9)
.	
6	
3	
STO	
1	
4	Max vehicle road speed in kph for selected vehicle, e.g. 48 for M60A1 (table 9)
8	
STO	
2	

—— Skip this section if only one vehicle is required on the program card.

.	Vehicle override diameter in meters for selected vehicle, e.g. .15 for M60A1 (table 9)
1	
5	
STO	
3	
6	Max road gradability in percent for the selected vehicle, e.g. 60 for M60A1 (table 9)
0	
STO	
4	
2	VCI_1 value for the selected vehicle, e.g. .25 for M60A1 (table 9)
5	
STO	
D	
4	VCI_{50} - VCI_1) value for the selected vehicle, e.g. (70 - 25) = 45 for M60A1 (table 9)
5	

STO

E

GTO

1

*

**

LBL

C — Identifies a third vehicle, e.g. M-113

2

.

6

9

(2 . 6 9) — Width of above vehicle in meters, e.g. 2.69 for M-113 (table 9)

STO

1

4

8

(4 8) — Max road speed of vehicle in kph, e.g. M-113 (table 9)

—— Skip this section if only one or two vehicles are required on the program card

STO

2

.

1

Vehicle override diameter in meters for selected vehicle, e.g. .1 for M-113 (table 9)

STO

3

6

0

Max road gradability in percent for the selected vehicle, e.g. 60 for M-113 (table 9)

STO

4

2

0

VCI_1 value for selected vehicle, e.g. 20 for M-113 (table 9)

STO

D

2

7

$(VCI_{50} - VCI_1)$ value for selected vehicle, e.g. (47 - 20) = 27 for M-113 (table 9)

STO	
E	
GTO	
1	
** ***	
LBL	
D	Identifies a fourth vehicle, e.g. T-72
3	Width of above vehicle in meters, e.g. 3.38 for T-72 (table 9)
.	
3	
8	
STO	
1	
6	Max road speed of selected vehicle in kph, e.g. 60 for T-72 (table 9)
0	
STO	
2	

—— Skip this section if only one, two, or three vehicles are required on program card.

$\boxed{.}$ $\boxed{1}$ $\boxed{8}$	Vehicle override diameter in meters, e.g. .18 for T-72 (table 9)
$\boxed{STO}$	
$\boxed{3}$	
$\boxed{6}$ $\boxed{2}$ $\boxed{.}$ $\boxed{5}$	Max road gradability in percent for selected vehicle, e.g. 62.5 for T-72 (table 9)
$\boxed{STO}$	
$\boxed{4}$	
$\boxed{4}$ $\boxed{5}$	VCI_1 value for selected vehicle, e.g. 45 for T-72 (table 9)
$\boxed{STO}$	
$\boxed{D}$	

1	$(VCI_{50} - VCI_1)$ value for selected vehicle, e.g. (60 - 45) = 15 for T-72 (table 9)
5	
STO	
E	
***	
LBL	
1	
R/S	
RCL	
4	
÷	
1	
−	
CHS	
RCL	
2	

X

STO

5

STO

0

R/S

STO

6

R/S

STO

7

ENTER ↑

RCL

6

–

RCL

$\boxed{1}$

$\boxed{-}$

$\boxed{\text{ENTER}\uparrow}$

$\boxed{\text{RCL}}$

$\boxed{1}$

$\boxed{\text{ENTER}\uparrow}$

$\boxed{2}$

$\boxed{\text{X}}$

$\boxed{\div}$

$\boxed{\text{STO}}$

$\boxed{8}$

$\boxed{\text{RCL}}$

$\boxed{3}$

$\boxed{\text{ENTER}\uparrow}$

$\boxed{\text{RCL}}$

$\boxed{6}$

f

X>Y?

GTO

2

x^2

RCL

1

X

RCL

3

x^2

RCL

7

X

÷

CHS

1
+
RCL
8
f
X>0?
GTO
3
X⇄Y
f
X>0?
GTO
4
CLX
STO
0

GTO

9

LBL

2

RCL

8

1

f

$X \leqslant Y?$

GTO

9

$X \rightleftarrows Y$

f

$X < 0?$

0

RCL

$\boxed{5}$

$\boxed{X}$

$\boxed{STO}$

$\boxed{0}$

$\boxed{GTO}$

$\boxed{9}$

$\boxed{LBL}$

$\boxed{3}$

$\boxed{f}$

$\boxed{X > 0?}$

$\boxed{GTO}$

$\boxed{5}$

$\boxed{CLX}$

$\boxed{1}$

$\boxed{f}$

$\boxed{X \leqslant Y?}$

GTO

9

X ⇄ Y

RCL

5

X

STO

0

GTO

9

LBL

4

1

f

X≤Y?

GTO

9

CLX

RCL

5

X

STO

0

GTO

9

LBL

5

1

f

$X \leqslant Y?$

GTO

9

$\boxed{\text{RCL}}$

$\boxed{5}$

$\boxed{\text{X}}$

$\boxed{\text{STO}}$

$\boxed{0}$

$\boxed{\text{LBL}}$

$\boxed{9}$

$\boxed{\text{R/S}}$

$\boxed{\text{RCL}}$

$\boxed{0}$

$\boxed{\text{X}}$

$\boxed{\text{STO}}$

$\boxed{0}$

$\boxed{\text{R/S}}$

$\boxed{\text{ENTER}\uparrow}$

$\boxed{\text{RCL}}$

$\boxed{\text{D}}$

$\boxed{-}$

$\boxed{\text{RCL}}$

$\boxed{\text{E}}$

$\boxed{\div}$

$\boxed{1}$

$\boxed{X \rightleftarrows Y}$

$\boxed{\text{f}}$

$\boxed{X > Y?}$

$\boxed{X \rightleftarrows Y}$

$\boxed{\text{RCL}}$

$\boxed{0}$

$\boxed{\times}$

$\boxed{\text{f}}$

$\boxed{X < 0?}$

$\boxed{\text{CLX}}$

$\boxed{\text{DSP}}$

$\boxed{0}$

$\boxed{\text{RTN}}$

g. Slide the PRGM-RUN button to RUN.

h. Follow Steps 8 through 11.

Step 13.

a. If there is no Program Card (figure 20) for the vehicle of interest, but there is a blank Program Card, proceed as follows.

b. Follow Part III, Steps 12b through 12f.

c. Slide the PRGM-RUN button to PRGM.

d. Insert the blank Program Card into the card reader slot as shown in figure 22 and explained in Part III, Steps 7e through 7h. The card now holds the Program for the vehicle of interest. Label the card with the vehicle identification number using a felt-tip pen or pencil that will not emboss the card.

e. Follow Steps 8 through 11.

IV. Qualitative Method - No-Model Approach

A. Introduction

This method * presents only three categories of Cross-Country Movement.

NO GO	Movement precluded except in local areas, or so difficult and tortuous that progess is essentially nil.
SLOW GO	Movement restricted or significantly slowed by obstacles that require bypassing, zigzagging, or detouring.
GO	Movement mostly free and easy. At least moderate speeds can be maintained for relatively long distances. Few, if any, time-consuming detours required to avoid obstacles.

To obtain these categories, all the factor overlays are examined for clearly NO GO and GO areas. These areas are transferred to the Complex Overlay. Then the factor overlays are re-examined with the aid of available maps, air photos, or literature to determine the nature of the SLOW GO areas, and perhaps extend the GO and NO GO areas.

With this method, a CCM map may be produced in less time than with the model methods, but the movement categories will be more general and qualitative.

* Method is based on one developed by A.H. Reimer and H.F. Barnett, USAETL TAC.

B. Procedures

Step 1.

a. Determine for what vehicle the CCM map is being prepared.

b. Obtain the following specifications for that vehicle from table 9:

Maximum slope (road gradability) (percent).
Maximum fording depth (m) (with or without snorkel).
Approach angle (degrees).
Vehicle width (m).
Vehicle override diameter (m).
Vehicle cone index, 50 passes (VCI_{50}).

c. Record this information on a reference table like the following:

VEHICLE TYPE – M-60

Maximum Slope (Road Gradability) (%)	60
Maximum Fording Depth (m)	1.22
Approach Angle ($^{\circ}$)	43
Vehicle Width (m)	3.63
Vehicle Override Diameter (m)	0.15
Vehicle Cone Index, 50 passes (VCI_{50})	70

Step 2.

a. Take the film positive or the lithographic map and the aerial photos out of the data base. Place them on a table. Take a clean sheet of frosted mylar, the same size as the film or lithographic map, and place it, frosted side up, on top of the film or lithographic map. Pin-register them or tape them together. Trace the corner tick marks on the mylar with a black fine-line pencil. Trace the neat line on the mylar lightly with a blue fine-line pencil.

b. Look through the mylar to find built-up areas. They will appear as clusters of building symbols or sometimes as tinted areas. Using a black fine-line pencil, draw an angular outline that will tightly enclose clusters of building symbols or tinted areas that cover an area larger than this circle ◯.* This sheet of mylar is now known as the Complex Overlay. Mark the built-up areas with the letter "N".

Step 3.

a. Remove the Complex Overlay.

b. Pull the Vegetation Factor Overlay and Vegetation Data Table 1 out of the data base. Register the Complex Overlay over the Factor Overlay.

c. Referring to Vegetation Data Table 1 and the table made in Step 1, note the map units with stem spacing equal to or less than the width of the vehicle. Trace the outlines of these map units with a black fine-line pencil.

d. Referring again to Vegetation Data Table 1 and the table made in Step 1, trace the outlines of all the vegetation areas that have mean stem diameters greater than the maximum vehicle override diameter.

e. Mark all the overlapping areas outlined in Steps 3c and d with the letter "N", which represents NO GO.

f. Trace the outlines of all the areas that have no trees, small trees (less than the maximum vehicle override diameter) or brush, or widely spaced trees (stem spacing greater than the vehicle width). Mark these areas with a "G", representing GO. If these areas should overlap an "N" area, change the "G" in the overlapped section to "N".

Step 4.

a. Replace the Vegetation Overlay with the Watercourses and Water Bodies Factor Overlay. Register.

b. Referring to the table made in Step 1, and the Watercourses and Water Bodies Data Tables 1 and 2, trace in blue all drainage reaches that have depths greater than the maximum vehicle fording depth, approach angles greater than the maximum for the vehicle, and any of the bottom conditions with RCI_{wet} listed in table 11 that are less than VCI_{50}. Mark these areas with an "N".

c. Trace the outlines of all swamps and marshes in blue. Label these with an "N".

---

* Represents an area of 0.25 km^2 at 1:50,000 scale.

Step 5.

a. Replace the Watercourses and Water Bodies Factor Overlay with the Surface Roughness Factor Overlay. Trace the outline of all map unit Areas 8. Label these with an "N". If these overlap an area marked "G", be sure to change the "G" area boundary to exclude the "N" area.

b. Trace the outline of all map unit Areas 1. Label these with a "G". If these overlap with an "N" area already on the Complex Overlay, be sure to change the "G" area boundary to an "N" area for that overlapped space.

Step 6.

a. Replace the Surface Roughness Overlay with the Slope Factor Overlay. Trace the outline of the areas with slopes greater than the vehicle maximum slope. Label these areas with an "N". An "N" overlapping a "G" becomes an "N" for that overlapped spaced.

b. Trace the outline of the areas with slopes less than 10 percent. Label these with a "G". If the "G" overlaps an "N" area already on the Complex Overlay, the overlapped space remains an "N".

Step 7.

a. Replace the Slope Factor Overlay with the Soil Factor Overlay. Trace outlines of all OL, OH, and Pt soil categories. Label these with an "N". Any "N" overlapping a "G" becomes an "N".

b. For Wet Conditions, follow Step 7a, but add all ML and CL soil categories. Label with an "N".

c. Trace outlines for all GW, GP, GM, and GC soil categories. Label these with a "G". Any "G" overlapping an "N" becomes an "N" for that overlapped space.

Step 8. Remove the Complex Overlay. On the Complex Overlay, combine adjoining areas having the same letter.

Step 9.

a. The remaining space on the Complex Overlay is probably SLOW GO. Label the remaining areas on the Complex Overlay "S" for SLOW GO. If aerial photos, maps, or literature are available, they should be examined for the areas labeled SLOW GO to see if there may be some GO and NO GO areas included in them. For example, air photos or written descriptions in the literature may reveal highly dissected terrain that might make part of the area NO GO, or reveal sand dunes stabilized by enough vegetation to make part of the area GO. Use the Qualitative Thresholds for CCM (table 13) to help locate these extra NO GO and GO areas. The "Good" movement condition on table 13 corresponds to GO; "Fair" and "Poor" corresponds to SLOW GO; and "Blocked" corresponds to NO GO.

b. Make the Complex Overlay neat (redraw if necessary), making sure that areas less than ¼ inch in the least dimension are combined with another category. Match all four sides with adjoining CCM sheets, and add the legend and marginal information. Edit the finished manuscript to ensure that it is completed and ready for drafting or distribution.

	Vehicle					
	XM-1	M-60	M-113	M-35	T-62	T-72
Gradability (%)	68.7	60	60	64	62.5	(62.5)
Max. Road Speed (kph)	71	48	48	56	50	(60)
Width (m)	3.65	3.63	2.69	2.43	3.37	3.38
Override Diameter (m) (at Breast Height)	0.25	0.15	0.1	.06		(0.18)
Vehicle Cone Index, 1 Pass (VCI_1)	24	25	20	30	23	45
Vehicle Cone Index, 50 Passes (VCI_{50})	56	70	47	69	68	(60)
Max Fording Depth, w/o Snorkel (m)	1.22	1.22	Swims	76	1.40	(1.40)
Max. Fording Depth, w/Snorkel (m)	2.34	2.44	Swims		5.00	(5.50)
Max. Stream Velocity Vehicle Can Cross (m/s)	(3.5)	3.4	1.8	(1.0)	(3.4)	(3.4)
Vehicle Approach Angle (°)	22.5	43	70	48		(32.5)
Max. Height, Vert. Obstacle (m)	1.24	.91	.61	.35	.80	(1.00)
Ditch Crossing Capability (m)	2.77	2.59	1.68	.55	2.85	(2.80)

( ) = Estimated

Table 9. Vehicle Performance Characteristics

MAP UNIT	SLOPE (%)	X-M1		M-60		T-62		T-72	
		S_1	NO GO	S_1	NO GO	S_1	NO GO	S_1	NO GO
A	0-3	67.9		45.6		47.6		57.1	
B	3-10	60.7		40.0		42.0		50.4	
C	10-30	40.0		24.0		26.0		31.2	
D	30-45	24.5		12.0		14.0		16.8	
E	45-60	9.0		0	X	2.0		2.4	
F	>60	0	X	0	X	0	X	0	X

Table 10. Precalculated S_1 for Selected Vehicles (kph)

USCS Symbol	RCI Dry Season	RCI Wet Season
GW	N/A	N/A
GP	N/A	N/A
GM	100^+	72
GC	100^+	90
GM-GC	100^+	81
SW	N/A	N/A
SP	N/A	N/A
SM	100^+	82
SC	100^+	82
SM-SC	100^+	82
ML	100^+	55
CL	100^+	46
ML-CL	100^+	51
OL	46	46
MH	100^+	83
CH	100^+	90
OH	40	40
Pt	35	35

Table 11. Approximate RCI Values for Wet and Dry Seasons (To be used ONLY for the cross-country movement calculations required in this guide when no other RCI values are available.)

Table 12. GLOSSARY OF SYMBOLS AND TERMS

$a < b$	a is less than b
$a > b$	a is greater than b
$a \leq b$	a is less than or equal to b
$a \geq b$	a is greater than or equal to b
$(a)(b)$	a x b, a multiplied by b

QUALITATIVE THRESHOLDS FOR CCM

MOVEMENT CONDITION	TERRAIN FACTORS													
	SURFACE CONFIGURATION		VEGETATION		SOIL/SURFACE MATERIAL						MICRORELIEF		CULTURE	
	WHEELED	TRACK	WHEELED	TRACK	WHEELED			TRACK			WHEELED	TRACK	WHEELED	TRACK
					DRY	WET	FROZEN	DRY	WET	FROZEN				
BLOCKED	Mountains & High Hills Badlands Cliffs Buttes & Mesas Haystacks Beehives Scabland Tidal Flats Eskers Kames Moraines Drumlins Talus	Mountains & High Hills Badlands Cliffs Buttes & Mesas Haystacks Beehives Tidal Flats	Scrub Mangrove Secondary Evergreen Forest Bamboo Windfall Jungle Primary Evergreen Forest Reeds & Rushes Vineyards Marshes & Swamps Tundra Underbrush Temperate Deciduous Forest Taiga Mixed Deciduous Forest Montane Forest	Secondary Evergreen Forest Mangrove Bamboo Windfall Jungle Marsh & Swamps Tundra Mixed Deciduous Forest Montane Forest	Loose Sand	Fine grained Tundra Peat Muskeg Muck Organic Soil Mobility Class E Silty gravels gravel-sand-silt mixture-GM Silty sands sand silt mix-SM Inorganic silts & very fine sands rock flow silty or clayey silts w slight plasticity ML CL ML Organic clays of med to high plasticity organic silts Mobility Class D Inorganic silts micaceous or diatomaceous fine sandy or silty soils elastic silts MH Organic silts and organic silty clays of low plasticity-OL	None	None	Tundra Muskeg Peat-Muck-Pt Mobility Class E	None	Boulder Fields Embankments Escarpments Frequent Ditches Sinkholes Badlands Hedge Rows Rubble Talus Scree Terraces	Boulder Fields Embankments Escarpments Badlands Hedge Rows Terraces	Cut & Fills Stone Walls Surface Pipelines Metro Area Tailings	Surface Pipelines Metro Area Tailings
POOR	Low Hills and Rolling Plains Volcanic Plains Dunes Wadis	Low Hills and Rolling Plains Volcanic Plains Wadis Eskers Kames Moraines Drumlins Talus	Shrub High Grass Open Forest Large Exposed Roots Row Crops Orchards Brush Rain Forest Monsoon Forest Open Forest	Primary Evergreen Forest Scrub Orchards Temperate Deciduous Forest Rain Forest Monsoon Forest Taiga Underbrush Open Forest	None	Clayey gravels gravel sand clay mixtures-GC Clayey sand sand clay mixtures-SC Gravely clays sandy clays inorganic clays of low to med plasticity lean clays silty clays-CL Mobility Class C	None	Loose sand	Clayey gravels gravel sand clay mixtures-GC Clayey sand sand clay mixtures-SC Gravely clays sandy clays inorganic clays of low to med plasticity lean clays silty clays-CL Mobility Class C	None	Freshly Plowed Ground Stoney Ground Large Exposed Roots Till	Frequent Ditches Sinkholes Rubble Talus Scree Till	Cattle Fences Suburban Development Type A old village center Type B closed orderly block	Cuts & Fills Stone Fences Suburban Development Type A old village center Type B closed orderly block
FAIR	Gently Rolling Plains Glacial Plains & Plateaus Coastal Plains Delta Plains Karst Plains Alluvial Fans Outwash Plains	Dunes Gently Rolling Plains & Plateaus Coastal Plains Delta Plains Karst Plains Alluvial Fans Outwash Plains	Savanna High Grass	Shrub High Grass Vineyards Row Crops Brush	None	Sand Inorganic clays of high plasticity fat clays Mobility Class B CH	None	None	Tundra Sand Inorganic clay of high plasticity Fat Clays Mobility Class B CH	None		Freshly Plowed Ground Stoney Ground	Type C dispersed family housing Type E industrial transportation	Type C dispersed family housing Type E industrial transportation
GOOD	Undulating & Flat Plains Lacustrine Plains Alluvial Plains Sand Plains Playas Hammadas (Bed-rock Fields) Desert Flats Flood Plains Plateau Prairie Steppe Pampas Bottom Lands Desert Pavement	Undulating & Flat Plains Lacustrine Plains Alluvial Plains Sand Plains Playas Hammadas (Bed-rock Fields) Desert Flats Flood Plains Plateaus Prairie Steppe Pampas Bottom Lands Desert Pavement	Low Grass Meadow Parkland Prairie	Low Grass Savanna Meadow Parkland Prairie	All but loose sand Coarse grained cohesionless sand & gravel Mobility Class A GW GP SW SP	Coarse grained Coarse grained cohesionless sand & gravel Mobility Class A GW GP SW SP Hardpan Laterite	All	All but loose sand	Coarse grained cohesionless sand & gravel Mobility Class A GW GP SW SP	All			Type D highrise area	Type D highrise area

Table 13. Qualitative Thresholds for CCM

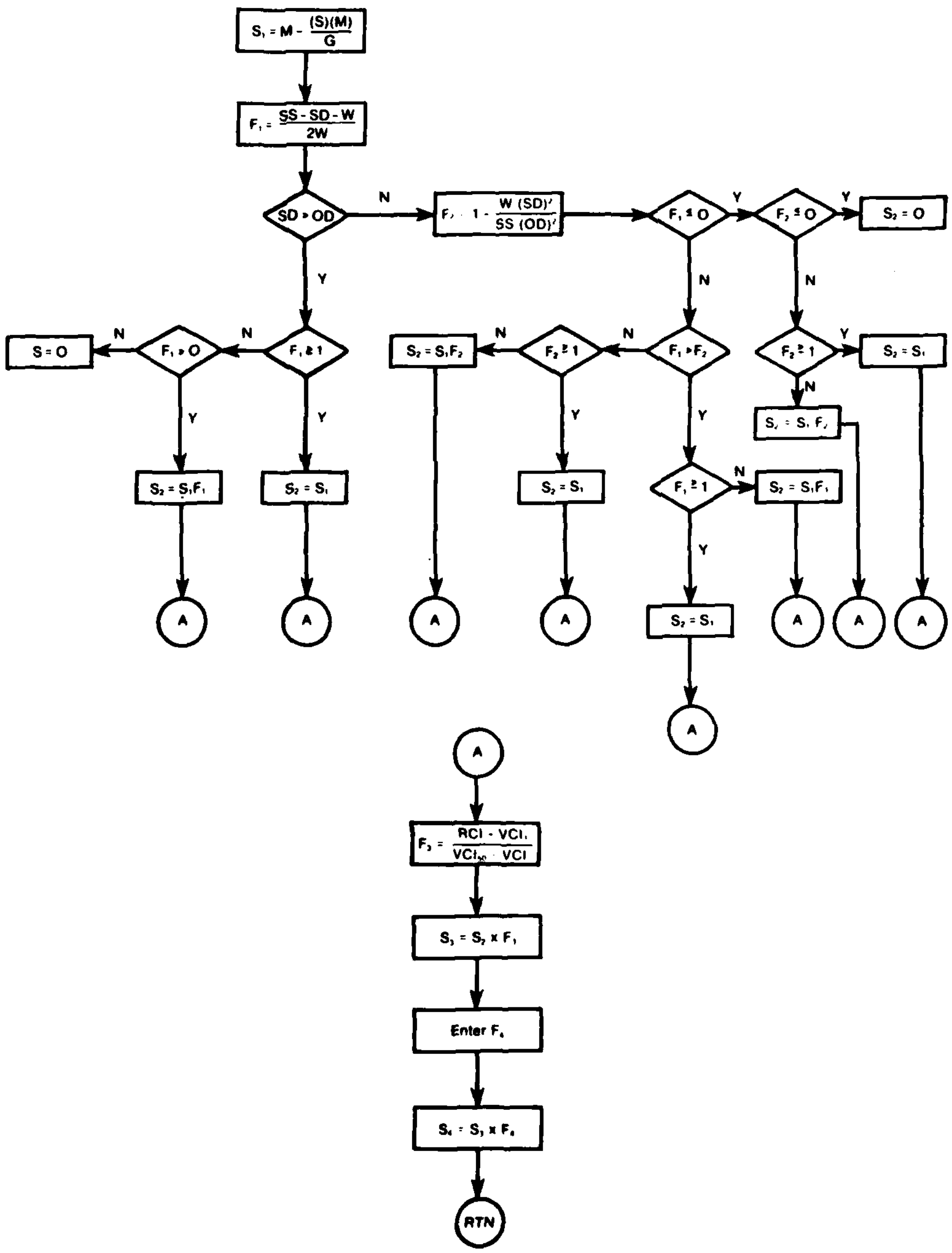


Table 14. Calculator Program Flow Chart

V. Appendix Forms

SOIL FACTOR TABLE

MAP UNIT	DRY			WET		
	RCI	F_{4D}	No-Go	RCI	F_{4W}	No-Go

MOVEMENT ANALYSIS OF DRAINAGE FEATURES

1	2	3	4a	4b	4c	5a	5b	6a	6b	6c	7a	7b	7c	8a	8b	8c
			WATER DEPTH			BANK HEIGHT AND BANK SLOPE					WATER VELOCITY			BOTTOM CONDITIONS		
ID NO	SEG	SEASON	VEH FORD DEPTH (m)	WATER DEPTH (m)	GO NO GO	VEH (m)	BANK HEIGHT (m)	VEH A A (°)	BANK SLOPE (°)	GO NO GO	VEH (mps)	WATER VEL (mps)	GO NO GO	VCI	BOTT RCI WET	GO NO GO

SPEED PREDICTION TABULATION SHEET #1

Sector A																
Area	SLOPE		VEGETATION				SURFACE ROUGHNESS			SOIL					CCM - Dry	CCM - Wet
	Map Unit	S_1	Map Unit	F_1	F_2	S_2	Map Unit	F_3	S_3	Map Unit	F_{4D}	F_{4W}	S_{4D}	S_{4W}	Map Unit	Map Unit

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